THESIS

ASPECTS OF ECOLOGY AND CONSERVATION OF PHEASANTS IN KUMAON HIMALAYA, UTTAR PRADESH, INDIA

SUMMARY

THESIS

SUBMITTED FOR THE DEGREE OF

Doctor of Philosophy

IN

WILDLIFE SCIENCE

BY

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SUMMARY

INTRODUCTION

Current status and ecological information on pheasants was lacking in Kumaon Himalaya. Therefore, this study was carried to fulfill the gap in information for this bird group. This study was part of the long-term ecological project titled "A study of threats to biodiversity conservation of the middle altitude oak forest of Kumaon Himalaya, India" funded by the Ministry of Environment & Forests, Govt. of India. The study was conducted in the five districts; Almora, Bageshwer, Champawat, Naini Tal and Pithoragarh of Kumaon Himalaya (28° 43' 55" and 30° 30' 12" N latitude and 78° 44' 30" and 80° 45' E longitude) covering an area of 21032 km^2 of Uttaranchal hills in India.

The main objectives of this study are-

1. To study the status and abundance of different pheasant species of Kumaon Himalaya.
2. To study various ecological aspects of different pheasant species of Kumaon.
3. To study social organization of different pheasant species of Kumaon.
4. To study food and feeding ecology of different pheasants of Kumaon.
5. To assess various threats upon different pheasant species as well as surveyed localities of Kumaon Himalaya.
6. To prepare a conservation strategy for each pheasant species and to suggest recommendation for their management and conservation.

METHODOLOGY

Fieldwork was carried out from March 1996 to December 1998 in Kumaon Himalaya. Overall 902 sampling plots were laid in 23 oak patches for vegetation assessment. Plot sampling method following Dombois & Ellenberg (1974) was used for vegetation sampling. Trees were quantified in 10m radius circular plot. Ground vegetation (herbs and grasses) was estimated in 0.5m x 0.5m quadrate at four places within the 10m radius circular plot. Tree cover was measured by using gridded mirror of 10 x 10 inches dimension.

The map boundaries of Kumaon were digitized from toposheets published by Survey of India. The area of proposed sanctuaries was also carved from the same toposheet. The data on different aspects were collected on grids of 1 x 1 km for the proposed sanctuaries. GIS analyses were performed by ArcView 3.2 computer software program.

Extensive surveys were conducted status and distribution of various pheasant species in Kumaon Himalaya. Trail monitoring was conducted to obtain relative abundance estimate of different pheasants. Call counts were conducted during breeding season to document presence of pheasant species, which might not be encountered during trail monitoring.

For habitat use, at each direct sighting or/indirect evidences, following records were made: a) Identification of species, b) General angle of slope, c) Habitat types, d) Weather condition. Vegetation was also quantified at the places where the pheasant species was sighted. Assessment of different disturbance factors was done on ordinal scale. In Binsar Wildlife Sanctuary, four existing forest trails, two in oak habitat and two in oak-pine, were used for monitoring while four trails were also selected for intensive monitoring in Pindari. Several threats on pheasants were identified and assessed.

ANALYSES

VEGETATION STUDIES

Densities for trees, shrubs and ground vegetation (herbs and grasses) were calculated. The diversity and richness for each layer (tree, shrub and ground vegetation) in different habitats and for each site was also calculated.

The vegetation of Kumaon was classified on the basis of all tree species sampled by using TWINSPAN (Two-way indicator species analysis) computer program. The same data matrix was again used for ordination of species as well as sites by using computer program DECORANA for Detrended Correspondence Analysis (DCA)

STATUS AND ABUNDANCE

The sightings of different pheasant species were summarized to calculate overall encounter rates (groups / 100 man hours of observation) for different sites for each species. The data obtained out of monitoring for pheasant species and quantification of habitat variables were arranged into species-habitat parameters and site characteristic matrix for performing multiple regression analysis. For spatial analysis, abundance of different pheasant species was divided into low (0-20), medium (20.1-40) and high (>40) categories. The habitat attributes (tree cover, shrub diversity, herb diversity and herb richness) were used as base theme layer and abundance of different pheasant species was overlaid.

HABITAT USE

Discriminant Function Analysis (DFA) was applied for five pheasant species to separate them on the basis of habitat attributes and various disturbance factors in Kumaon Himalaya. Factor analysis was applied on habitat used (utilized) by each species. General vegetation sampling on the trails was considered as available (availability) habitat for pheasant species. Later logistic regression analysis was performed using extracted factor scores from the analysis to estimate the probability of correct classification of pheasant species plot (utilized) and general available habitat plot (available).

FEEDING ECOLOGY

The faecal matter (droppings) of Kalij, Koklass, Himalayan Monal and Satyr Tragopan were collected on the trails from Pindari reserve forest only. The collection was made season wise to compare difference in food items of these species. Major ground vegetation species were collected and identified from the places where droppings were found. A total of 40 reference slides of different plant species were prepared.

The prevalence of each food item was expressed as a Food Importance Index (Bhandary *et al.* 1986). By using the frequency and composition of food items the Food Importance Index (FII) was calculated by following formula,

FI I = % Frequency + % Composition / 2

Kruskal-Wallis one-way ANOVA and t-test were performed (Zar, 1984) on different food items to observe significant difference among pheasant species season wise. Based on the composition of each food item identified from the droppings of pheasant species was categorized into three groups, 1) Major food components or those food items forming >10% of the total composition; 2) Minor food components or those items forming <10% but >3% and 3) Trace items which formed <3% of the total composition.

SOCIAL ORGANIZATION

Chi-square goodness of fit was used to determine the differences in group composition between the seasons for both the intensive sites. Chi-square contingency test was performed to see the difference in either sex individual groups or the groups having both the sexes between the seasons. Groups of different species were also categorised as solitary, two or groups having ≥3 individuals and Chi-square contingency test was applied to observe the difference in the group size range between the seasons.

THREATS AND CONSERVATION STATUS

Trees were categorised arbitrarily into six GBH classes and height of fire was also categorized into eight classes. Tree species diversity and richness was calculated for different fire height categories and GBH classes. The Importance Value Index (IVI) for each tree species was calculated.

Percentage of overall dead trees and percent dead of each tree species was calculated for each fire affected patches. The Bonferroni confidence intervals were constructed following to detect significant differences in species-specific mortality pattern. Top five IVI ranking dead tree species and different GBH classes were taken into account for chi-square contingency test to pin point the association between the dead tree species and GBH classes while the same test was performed for top four IVI ranking dead tree species and different height categories to pin point the association between dead tree species and different height categories.

To generate threat index for all the surveyed sites, each threat parameter was converted into the ordinal scale ratings of low (1), medium (2), and high (3). All the converted ratings of threats were added together and then divided by number of threat parameters.

The surveyed sites were categorised, on the basis of generated mean threat score. A definite range of mean threat score was given to each threat category. The low threat category was taken between 0-1 mean threat score, the medium was between 1.1-2 and >2 was accounted for high.

Combined conservation value for Kalij, Koklass, Himalayan Monal, Satyr Tragopan and Cheer pheasant was calculated. Conservation value was also calculated for each surveyed patch on the basis of pheasant species composition. For this, six attributes were taken into consideration i.e. Altitudinal range occupied by each pheasant species in Kumaon, Extent of path size for species abundance, Degree of disturbance, Degree of restricted distribution of each species in Kumaon, Degree of endangerment for each pheasant species and Degree of legal status of the area provided to each pheasant species. Conservation value for each surveyed site was calculated by combining the conservation value of each species represented by the sites.

RESULTS

VEGETATION STUDIES

A total of 63 tree species, 56 shrub species, 90 herb species and 21 grass species were sampled in 23 oak patches of Kumaon Himalaya. Nineteen broad habitat types had been recognized in Kumaon. Total five homogenous groups in relation to environmental variables were identified.

DCA produced the extreme diversity of tree communities from low altitude to high altitude. Its first axis was altitude gradient, which represented ecological series from low altitude, middle altitude and high altitude communities. Axis 2 reflected shrub characters and canopy cover gradient. 17 broad communities of 52 shrub and herb species had been recognized by TWINSPAN, which identified major identical homogenous groups.

The tree density was significantly high at Gasi (995.2 ± 269.4) while shrub density was highest for Gager (24504.6 ± 11280.7). The tree layer was dominated by *Rhododendron arboreum* (3861.41 / ha). *Myrcine africana* (91299.86 / ha) was the dominant shrub species and it was maximum at Kunjakharak (13269.64/ha). Tree species diversity was maximum at Daphiadhura (1.53). Tree species richness was maximum at Daphiadura (1.76). Shrub diversity and richness were highest in Vinaiyak (1.61, 1.54).

STATUS AND ABUNDANCE

Five pheasant species were documented from the surveyed region.

Whitecrested Kalij (*Lophura leucomelana*): It was found at 14 sites out of 23 sites between the altitude range from 1660 - 2550m.

Koklass (*Pucrasia macrolopha*): The species was found to be most abundant and widely distributed among all the pheasant species found in Kumaon. The species was sighted or / heard at 15-20 at sites between the altitudinal range from 1830 - 3180m.

Cheer pheasant (*Catreus wallichii*): This species was found to be the most threatened species among all the pheasant species occurring in the Kumaon Himalaya and the species was encountered at two sites only between the 2300- 2520m altitude range.

Himalayan Monal (*Lophura impejanus*): The species was seen between the altitude range from 2520-3300m. The Monal was encountered at four sites out of 23 surveyed sites.

Satyr Tragopan (*Tragopan satyra*): The species was seen at three locations in Kumaon with few encounters between the altitude range from 2280-3140m.

HABITAT USE

The analysis produced four functions DF1, DF2, DF3 and DF4 accounting for 100% variation between the species. The first discriminant function represented variation in altitude from low to high. The second function described vegetation components while function third represented areas from open to close canopy forest with simultaneously increase in percentage of cover in shrub layer. Kalij was distributed in the areas having low percentage of grass cover with enough herb density at low altitude. Koklass preferred areas having very low grass cover and abundant herb density at middle altitude. Cheer was associated with the areas having high percentage of grass cover with limited number of herbs at middle altitude while Satyr Tragopan was present in the areas with low percentage of grass cover at higher altitude. Monal was separated from the rest by holding areas having medium percentage of grass cover and medium herb density at higher altitude.

Binsar Wildlife Sanctuary

Kalij: During premonsoon season, PCA extracted seven components for Kalij. PC1 described high altitude, close canopy, mature forest with low rocky area having less grass cover, PC II was highly positively correlated with grass density, grass diversity, grass richness and herb diversity, herb richness and negatively correlated with tree richness and

PC III was related with low altitude, open canopy forest with high ground cover. These three components showed significant difference in the use of random and bird plots (PC I $U = 250, p < 0.004$; PC II $U = 214, p < 0.001$; PC III $U = 278, p < 0.01$).

Postmonsoon season PCA extracted 7 factors (72.32% variance). PC I described close canopy, high tree density, more shrub cover and shrub richness and more bare ground with less grass cover and grass density habitat. PC II explained more ground cover and low tree cover and less withered stone area. PC III explained close canopy dense forest with low percentage of herb cover.

Koklass: Eight components were extracted by PCA, which explained 82.66% variance for premonsoon season. First factor represented high altitude, more tree cover and shrub cover area with low grass density. II factor was associated with high grass density, diversity, grass richness and herb density with low tree richness. III factor again described more ground cover with less canopy cover habitat. U-test revealed significant difference in the random and bird plots on the basis of PC II.

Seven factors were extracted by PCA (71.90% variance) for premonsoon season. PC I described mature forest of high tree density and shrub density, shrub diversity and shrub richness with high litter cover and low grass cover. PC II had high positive loadings of grass density, grass diversity, grass richness and grass cover while negative loadings of tree cover and litter. PC III depicted the forest of high tree density and tree diversity with low herb cover on gentle slope. There was significant difference in available and utilized habitats by Koklass on the basis of PC III ($U = 576, p < 0.008$).

Pindari Reserve Forest

Koklass groups were encountered more in mixed habitat while groups of Monal were encountered maximum in oak-coniferous habitat. Satyr did not show any significant difference between different habitat types during premonsoon while during postmonsoon significant difference were observed. Koklass was seen more in mixed habitat while Monal was encountered more in oak-coniferous habitat during postmonsoon season also.

Kalij: Overall 9 factors were extracted by PCA, which accounted for 82.44% of variance for premonsoon season. The first factor described mature forest at low altitude and gentle slope with low grass diversity. II factor reflected the forest with high ground cover and low shrub cover at high altitude and III factor was summarized as low altitude, high shrub cover area with high tree richness at steeper slope.

Koklass: Six factors were extracted by PCA (70.05% of variance) for premonsoon season for Koklass. First factor depicted a high ground cover forest area. II factor was highly positively correlated with herb diversity, richness, density and shrub density and negatively correlated with slope and tree cover. III factor represented low altitude area with high tree diversity and richness. PC I was significant suggesting that there was significant difference in the use of habitat variables in the random and bird observed plots.

First three factors explained 43.92% variance for postmonsoon season First component described high herb cover, herb density, grass density, cover and low tree cover, density and litter. II factor summarized high herb and grass density, diversity and low shrub richness and rock cover. III factor represented forest areas at lower altitude having high tree diversity and richness. U-test also revealed that significant difference in the use of habitat variables in the random and bird observed plots on the basis of PC I and PC II.

Monal: PCA extracted six components, which explained 71.43% variance. The first three components explained 50.68% variance for Monal for premonsoon season. First component represented forest areas at low altitude having high tree diversity, richness and density. II component represented areas with low altitude, high ground cover and dense and rich shrub cover. III component described high ground cover and low litter. U-test showed significant difference in the random and Monal observed plots on the basis of PC I, PC II and PC III.

During postmonsoon season, PCA extracted seven components, which accounted for 73.89% of variance. PC I summarized the forest areas at low altitude, high ground cover and low shrub cover with gentle slope. PC II showed high positive loading of tree cover, density and litter while negative loading of grass density, herb density and shrub richness. PC III represented areas with high ground cover with low shrub density and litter. Mann-Whitney U-test showed significant difference in the use of habitat variables in the Monal observed and random plots on the basis of PC I ($U = 38$, $p < 0.00$) and PC II ($U = 268$, $p < 0.001$).

Satyr Tragopan: PCA extracted seven components (75.27% of variance) for Satyr Tragopan for premonsoon season. The first factor represented low altitude forest with high tree density and litter and low ground cover. II factor explained the forest with high ground cover with low litter and III factor represented low altitude, steep slope and high shrub density, shrub cover and shrub richness. U-test revealed significant difference in the use of habitat variables on the basis of PC II ($U = 255$, $p < 0.00$).

During postmonsoon season, PCA extracted eight components, which accounted for 78.58% of variance. First component described the forest areas with high ground cover and low tree cover, tree density and litter. II component represented high ground cover and lower shrub area at lower altitude. III component seemed to be a wooded forest with high tree diversity and richness on low altitude. The use of the PC II ($U = 51$, $p < 0.00$) showed significant difference in the use of habitat variables in the random and bird plots.

FEEDING ECOLOGY

Total 38 food items were identified in Kalij, Koklass, Himalayan Monal and Satyr Tragopan from faecal matter. Out of these 38 items, 36 were plant materials whereas rest were grit and invertebrates.

Total 11 food items were identified from the droppings of Kalij during premonsoon season and postmonsoon seasons. No significant difference occurred in composition of different food items identified for premonsoon season ($F = 1.82$, d.f. = 10,100, $p > 0.07$) but significant difference ($F = 5.13$, d.f. = 10, 100, $p < 0.00$) in composition of different food items occurred in Kalij droppings during postmonsoon season. The occurrence of invertebrates during premonsoon and postmonsoon was not significant whereas other food items were significantly different during seasons.

A total of 14 food items were identified from the Koklass dropping during premonsoon season while 15 food items were identified for postmonsoon season. Significant difference in different food items in premonsoon season ($F = 5.31$, d.f. = 14, 135, $p < 0.00$) was observed.

A total of 13 food items were identified during premonsoon season in the droppings of Himalayan Monal. Significant difference in different food items obtained from the faecal analysis of Monal ($F = 5.22$, d.f. = 12, 126, $p < 0.00$). Out of 13 food items of Monal, the percent composition of three of them fluctuated in both the seasons.

A total of 17 food items from were recorded from the faecal droppings of Satyr collected in postmonsoon season. Fifteen of these were plant material. Significant difference was observed in various food items ($F = 2.54$, d.f. = 15,144, $p < 0.002$).

Sorenson's similarity index showed the highest similarity between the food composition of Koklass and Satyr (SI = 0.64) while Kalij and Monal were least similar in their diet composition (SI = 0.17).

Grit and invertebrates were the common food items in all pheasants in both the seasons. Significant difference in the percent composition of invertebrates was found in all pheasants ($F = 3.78$, d.f. = 3, 36, $p < 0.018$) during premonsoon season and postmonsoon season ($F = 14.7$, d.f. = 3, 36, $p < 0.00$). The percent composition of grit was not significantly different in all pheasants in both the seasons.

SOCIAL ORGANIZATION

Binsar Wildlife Sanctuary

Kalij: Overall 66 separate groups of Kalij were seen during premonsoon season. The overall mean group size was 2.31. More solitary birds than individuals of two or three in a group were encountered. The overall sex ratio was 150 males / 100 females. No significant difference ($\chi^2 = 0.533$, d.f. = 2, $p > 0.05$) was observed between all male groups, all female groups and the groups having both sexes between premonsoon and postmonsoon seasons. The sex ratio was 137 males / 100 females during postmonsoon season.

Koklass: Overall 13 groups comprised all male individuals and 7 groups had all female individual groups and on 11 occasions they were found together. No significant difference ($\chi^2 = 1.9$, d.f = 1.9, $p > 0.05$) was observed across the season in the groups having all males, all females or mixed individuals. The overall sex ratio was 115 males / 100 females while it was 175 males / 100 females during premonsoon season with equal sex ratio during postmonsoon season.

Pindari reserve forest

Kalij: A total of 6 sightings comprised all male individual groups, 5 groups contained all females and 13 groups had mixed individual groups. The group size for postmonsoon season was 2.25. Equal sex ratio (1:1) was observed across the seasons.

Koklass: Overall 33 groups had all male individuals, 23 groups had all females in their groups and 51 groups had both the sexes. The overall group size was 1.7. Koklass formed more groups having ≥3 individuals during premonsoon while they preferred to form solitary or two individuals in their groups during postmonsoon season. The sex ratio of the area was 105 males / 100 females.

Himalayan Monal: Overall 23 groups had all male individuals in their groups, 6 groups were all female groups and 12 groups contained mixed individuals. Overall significant difference ($\chi^2 = 10.91$, d. f = 2, $p < 0.05$) was observed in the encounters with either sex groups or with mixed individual groups. The overall mean group size for the area was 1.7 while it was 1.4 for premonsoon season and 2.2 for postmonsoon season. The overall sex ratio for the area was 214 males / 100 females, which differed significantly between the seasons.

Satyr Tragopan: 13 groups comprised 4 groups of all male, 6 all females groups and 3 groups represented both sexes. Overall mean group size for the area was 1.4. The overall sex ratio for the species was 100 males / 100 females.

THREATS AND CONSERVATION STATUS

In the burnt patches, maximum mean density of tree species was quantified for Jageshwer and minimum for Daphiadhura. Maximum regeneration of different tree species was observed at Daphiadhura while minimum in Binsar. Tree species diversity and richness was maximum at Jageshwer while minimum diversity and richness was in Binsar.

Maximum tree species mortality (48.37%) was observed for *Quercus leucotricophora* and minimum mortality (0.001%) in case of *Pyrus pashia* Binsar WS. The maximum IVI (95.51) was accounted for by *Quercus leucotricophora* and considered as the most dominant tree species. The minimum IVI was calculated for *Euonymous* species (2.93). While at Daphiadhura (AWS) *Quercus lanuginosa* had the maximum IVI (120.3), while minimum IVI (4.85) for *Myrica esculenta*, *Quercus floribunda* etc.

Significant difference was observed between GBH classes of dead trees ($F = 33.85$, $d.f = 5,20$; $p < 0.01$) in BWS. Significant difference was also observed in the dead trees of different tree species ($F = 5.28$, $d.f = 4,20$; $p < 0.01$). The highest mortality was found in the GBH class 0-25 cm and maximum mortality was found in 0-26 cm GBH class for *Viburnum mullaha* and least mortality was found in >51 cm for *Lyonia* *ovalifolia* in BWS. In Daphiadhura the result was not significant for top five IVI ranking tree species ($\Sigma\chi^2 = 6.74$, d.f. = 6; $p > 0.06$).

Significant difference was observed between different fire height categories in the dead trees ($F = 4.3$, d.f = 7, 28, $p < 0.01$) in BWS. Maximum mortality was found in >801 cm fire height category while it was least in <200 cm category. In Daphiadhura the category 801-1600 cm was most affected while in Jageshwer category >801 cm was most affected. *Viburnum mullaha* representing the fire height category 401-800 cm was most affected and the category >800 cm was least affected in the same species.

In BWS mortality of *Rhododendron arboreum* (18.79%), *Euonymous* sp. (0%), *Symplocos theifolia* (0%) and *Toona serrata* (0%) was significantly less than expected according to availability while other species had significantly higher mortalities than expected. *Quercus lanuginosa* (18.85%) in Daphiadhura, *Pyrus pashia* (0%) and *Litsea umbrosa* (0%) in Jageshwer had significantly less mortality than expected according to availability. But *Lyonia ovalifolia* (72.42%) had significantly more mortality than expected in Jageshwer.

Total 18 regenerating tree species were encountered in BWS. Maximum regeneration was accounted for by *Swida oblonga* (31.14%) and minimum regeneration (0.2%) was recorded for *Persea duthiei.* A total of nine and 12 regenerating (seedlings) tree species were found in Jageshwer and Daphiadhura respectively. Maximum regeneration was observed for *Quercus leucotricophora* (43.75%) at Jageshwer while *Quercus lanuginosa* (42.02%) at Daphiadhura. Minimum regeneration was observed for *Litsea umbrosa* (0.89%) at Jageshwer while *Pyrus pashia* (0.36%) and *Lindera pulcherrima* (0.36%) at Daphiadhura. 11 tree species at sapling stage were recorded from

Binsar. Maximum mortality was found in *Lyonia ovalifolia* (64.29%). Total eight and nine tree species (saplings) were recorded from Jageshwer and Daphiadhura respectively. Maximum mortality at Jageshwer was recorded for *Rhododendron arboreum* (60%). The maximum mortality observed for the *Lyonia ovalifolia* (26.31%) while minimum mortality was recorded for *Pyrus pashia* (0.58%).

The generated mean threat score for surveyed sites varied from 0.78 to 2.3. On this basis, the sites Jilling and Sunderdunga have fallen under low threats (0-1 mean threat score) while Binsar Wildlife Sanctuary, Sitlakhet, Jageshwer, Pindari, Gandhura (AWS) and Munsiary under high threats (>2 mean threat score) and rest of the sites had fallen under medium threat category (1.1-2 mean threat score). The regression coefficient of fuel wood collection was highly related with human population, land area available for different purposes and source of income through different means. The factors human population and source of income together accounted for 68.6% of variation in fuel wood collection ($F = 21.86$, $p < 0.001$).

The Satyr Tragopan was the highest ranked species followed by the Himalayan Monal and Cheer pheasant while Whitecrested Kalij and Koklass obtained least conservation status. None of the pheasant species in Kumaon were found in the category 'substantial portion of the global range in the Himalayas'. The maximum conservation status was obtained for Pindari (3.76), followed by Wachham (3.16), Sunderdunga (2.55), Munsiary (2.55) and Vinaiyak (2.23). All the five species of pheasants were found in Pindari while the presence of Cheer pheasant at Wachham and Vinaiyak upgraded the conservation status of these sites. The localities such as Sitlakhet and Gasi were having nil conservation status in terms of pheasants. Kilbery and Kunjakharak also had low conservation status by having Kalij and Koklass.

No significant relationship between pheasant species composition and threat index in spatial analysis was observed. Map showed that only Pindari had maximum pheasant species in spite of being a high threat area. While Binsar, Munsiary and Gandhura had medium species composition. Sunderdunga and Jilling had fallen under low threat category and also had medium species composition. Except Dhakuri, Sunderdunga, Pandavkholi, Maheshkhan, Jilling, and Sobala all patches experienced high threats in terms of set of threat parameters (cutting, lopping, grazing, grass harvesting, human & livestock population and surveyed forest patch size) experienced by each surveyed forest patch.

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(Formerly Centre of Wildlife & Ornithology)

ALIGARH MUSLIM UNIVERSITY, ALIGARH-202002 [INDIA]

Ref No *Dated*

CERTIFICATE

This is to certify that the thesis titled **"Ecology and conservation of avian communities of middle-altitude oak forest of Kumaon Himalaya, Uttar Pradesh, India"** submitted for the award of Ph.D. degree in Wildlife Science, of the Aligarh Muslim University, Aligarh is the original work of **Aisha Sultana**. This work has been done by the candidate under my supervision.

Jamal A Khan

Jamal A Khan, Ph.D.

Date: 22 April 2002

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WORLD WIDE CONSERVATION OF GALLIFORMES

CERTIFICATE

This is to certify that the thesis titled, " Aspects of Ecology and Conservation of pheasants in Kumaon Himalaya, Uttar Pradesh, India", submitted for the award of Ph.D. degree in Wildlife Science, of the Aligarh Muslim University, Aligarh is the original work of [redacted] The candidate has carried out this work under my co-supervision.

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DEDICATED TO MY FAMILY

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CHAPTER 3 VEGETATION STUDIES

CHAPTER 4 STATUS AND ABUNDANCE OF PHEASANT SPECIES

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CHAPTER 1

INTRODUCTION

1.1 RATIONALE

The conservation of biodiversity is perhaps the greatest global environmental concern facing mankind today. India like other developing and overpopulated parts of the world faces greater threats. Changes driven by unprecedented level of human demands on natural resources brought changes in qualitative as well as quantitative state of forest of the country. The country has been left with only 19.27% of forest cover and out of it only 11.44% is dense forest cover (Anonymous, 1997). The change in forest cover throughout the country resulted in rapid depletion of biological diversity. Wildlife being a component of biological diversity, its population too suffered in this process.

Himalayas constitute a significant unit in the Indian subcontinent and has unique and extremely rich repositories of natural resources and biological wealth. The biota of the Himalayas has undergone change due to deforestation and similar trend was also observed in the Western Himalayas (Tucker, 1987). Consequently, considerable area in the Western and Central Himalaya lost its forest cover. The existing forest cover is highly fragmented and degraded due to excessive biotic pressures, excessive livestock grazing and firewood and fodder collection (Gaston & Garson, 1992).

The middle altitude climax oak forest (Singh & Singh, 1986), rich in biological diversity, used to be extensively distributed in the Kumaon Himalaya. Concentrations of human settlement in the oak forest area, lopping and tree felling and unusual fire events have reduced the area under oak forest (Champion & Seth, 1968 and Singh *et al.* 1984). The reduction in much of the oak forest area may be regarded as 'endangered' (Singh & Singh, 1987) because much of the area under oak forest in the past, is either barren, terraced for agricultural purposes or has been replaced by chir-pine forest. The broad-leaved oak forest is considered to house rich biological diversity. The changes brought by anthropogenic pressures and replacement of broad leaf forest by chir-pine affected distribution of most of the wildlife species (birds and mammals) in the Kumaon Himalaya and they are surviving in extremely low numbers. Similar effect was observed in the family phasianidae, which has also suffered from hunting in the past.

1.2 PHASIANIDAE- ABOUT THE FAMILY

The family phasianidae belong to the order Galliformes that includes partridges, francolins, snowcock, quails and pheasants in it, and they are collectively called as gamebirds. The earliest records of classification came from Beebe (1914) who used the sequencing of moulting in retrices (tail feathers) as the main criterion for generic groupings for the family phasianidae. On this basis, the family was further divided and the species exhibiting variation in the moulting sequencing were included in subfamily. *Ithaginis* (Blood pheasant) and *Tragopan* (Tragopan pheasant) along with partridge like species were included in the subfamily Perdicinae (centrifugal moulting pattern) while the typical pheasants were included in Phasianinae (centripetal moulting pattern). The typical Peafowl (moulting beginning from the second retrices from the outer, with outer most moulting before the inner ones) and Peacock and Argus pheasants (moulting beginning with the third from central and proceeding outwards and inwards simultaneously) were exception to this family and were placed in the group Pavoninae and Argusianinae respectively. Delacour (1977) included the New World quails in the subfamily Phasianinae though he found *Ithaginis* and *Tragopan* related to the partridges but considered them sufficiently pheasants. Verheyen (1956) suggested skeleton measurement of the pheasants as the basis of classification. According to Verheyen (1956) the subfamily Phasianinae included pheasant like species, the subfamily Afropavoninae included Congo Peafowl *Afropavo congensis* while Pavoninae included Peafowl. Johnsgard (1973, 1986) classified pheasants as a separate subfamily Phasianinae under the broad family phasianidae tribe Phasianinae. Wolters (1975) proposed the most widely used form of pheasant classification and also considered the Guinea fowl to be one of the 15 subfamilies of the family phasianidae. More recently Sibley & Monroe (1990) classified the pheasants and Old World partridges, quail and francolins under the family phasianidae.

Out of sixteen genera (Delacour, 1977) and 51 species (69 taxa) of pheasants, 50 species are endemic to Asia (McGowan & Garson, 1995) with a single species the Congo Peafowl is native to Zaire in central Africa (Crowe *et al.* 1986). Human into various parts of Europe and USA has introduced several species for sport-hunting purposes (Bump, 1941; Pokorny & Pikula, 1987 and Hill & Robertson, 1988a).

In Asia, pheasants occur from Flores, east of Java at about 8°S, through equatorial forests of the Thai-Malay Peninsula, to northeastern China 50° N and from 145° E in the Caucasus to 145° E of Japan. Pheasants inhabit variety of vegetation types throughout their distribution range such as lowland tropical forests (Crested fireback *Lophura ignita*), temperate coniferous (Western Tragopan *Tragopan melanocephalus*), sub-alpine scrub (Blood pheasant *Ithaginis cruentus*), montane grass scrub (Cheer pheasant *Catreus wallichii*) and broad leaf evergreen (Kalij *Lophura leucomelana* and Koklass *Pucrasia macrolopha*) also.

Knowledge of individual taxa is poor and very little basic ecological information is available on 47 (68%) taxa of pheasants (Fuller & Garson, 2000). Of the 69 taxa of pheasants 4 (6%) are critically endangered with extinction, 16 (23%) are endangered, 24 (35%) are vulnerable, 19 (27%) have been categorized as safe from extinction and 6 (9%) are considered to be insufficiently known to be assigned threat categories.

Of the 51 species of pheasants 17 species occur in Indian limits and out of it 16 are confined to the Himalayas. The species account with their status are given below-

a. **Blood Pheasants (Safe).** This group represents a single species *Ithaginis cruentus* with three subspecies. The *Ithaginis creuntus affinis* is distributed in Sikkim, *I.c tibetanus* in east Bhutan and Western Arunachal Pradesh and *I.c. kuseri* is distributed in eastern Arunachal Pradesh.

b. **Tragopan Pheasant (Endangered and Vulnerable).** Tragopan comprises four species, the Western Tragopan, *Tragopan melanocephla* is distributed in the Western Himalaya from north Kashmir to east Uttar Pradesh, Satyr Tragopan, *Tragopan satyra* in Kumaon, Darjeeling hills, Sikkim and Arunachal Pradesh, Blyth Tragopan, *Tragopan blythii blythii* in Assam, Mizoram, and Manipur and Temminck's Tragopan, *Tragopan Temminckii* is distributed in Arunachal Pradesh.

c. **Koklass Pheasant (safe).** This is found in Western Himalaya and is represented by single species *Pucrasia macrolopha* with two subspecies. *P.m. biddulphi* is distributed in Kashmir and Himachal Pradesh while *P. m. macrolopha* from southern Kashmir to Garhwal Himalaya.

d. **Monal Pheasant (Safe).** This is represented by two species. Himalayan Monal, *Lophophorus impejanus* is distributed all along the Indian Himalaya from west to east and endangered Sclater's Monal, *Lophophorus sclateri* is found in Arunachal Pradesh.

e. **Junglefowl (Safe).** Represented by two species. The Red Jungle fowl, *Gallus gallus* represented two subspecies. The Indian Red junglefowl, *Gallus gallus murghi* are distributed from Kashmir to Arunachal Pradesh southward to parts of Uttar Pradesh, Madhya Pradesh, Bihar, Orissa, West Bengal and Assam. The subspecies, Burmese Red Jungle fowl, *Gallus gallus spadicus* is found in eastern Mishmi hill in Arunachal Pradesh. The second species Grey Jungle fowl, *Gallus sonneratii* is confined to areas of southern Rajasthan, Madhya Pradesh, Gujrat, Tamil Nadu, and Kerala in India.

f. **Kalij Pheasant (Safe).** It represents single species with four subspecies. Whitecrested Kalij, *Lophura leucomelana* is found in the Western Himalaya, Black-backed Kalij, *Lophura leucomelana melanota* is found in east central Himalaya, Black-breasted Kalij, *Lophura leucomelana lathami* are confined to Arunachal, adjoining Myanmar and Manipur and Williams Kalij pheasant, *L.l. williamsi* is distributed in southeast Manipur and hills of Mizoram contiguous with chin hills of Myanmar.

g. **Tibetan-Eared Pheasant (Endangered).** In India this genus is represented by single species, *Crossoptilon harmani* and it is confined to the northern areas of Arunachal Pradesh.

h. **Cheer Pheasant (Vulnerable).** *Catreus wallichii* is the single representative species of this genus and is found in the Himalayas from Kashmir through Garhwal to Kumaon.

i. **Hume's Pheasant (Endangered).** This genus is represented by single subspecies *Syrmaticus humiae humiae* distributed in Manipur, Patkai, Naga and Mizo hills of northeast India.

j. **Peacock Pheasant (safe).** This group represents single species called Bhutan Peacock Pheasant, *Polyplectron bicalcaratum* distributed in Sikkim, North Bengal, Arunachal Pradesh, Assam, Manipur and Nagaland.

k. **Peafowls (Safe and endangered).** Two species of this pheasant are found in India. The common Indian Peafowl, *Pavo cristatus* distributed upto 1800m throughout the country while rare and endangered Green Peafowl, *Pavo muticus spicifer* is suspected to be present in the areas lying adjacent to southeastern Bangladesh.

In the wake of massive deforestation in the Himalayan region, the survival of pheasants stands threatened. Increased consumption of many pheasant species has resulted in severe threats to the survival of these species. Presently six species are threatened with extinction in the Red data book of IUCN (Fuller & Garson, 2000) and require urgent protection for their long-term conservation in the Indian Himalayas.

The conservation of pheasants in the Himalayas is essential for a number of reasons. Pheasants belong to a highly specialized group of avian inhabitants of a very fragile habitat where the least human exploitative pressure sets off irreversible chain reaction and their status in any natural habitat can be considered as an index of the well being of that ecosystem (Jayal, 1982). Pheasants help in litter decomposition by uprooting and scratching the ground for food. They also form food base for many mammalian carnivores and large birds of prey. Many of these would not have survived in the absence of healthy pheasant population.

Most of the pheasants are ground nesters and need plenty of vegetative cover (Johnsgard, 1986). These entire characteristics tend to make them more prone to local extinction due to habitat fragmentation and degradation. Hence, for effective and long-term conservation of pheasants and management of large pristine and undisturbed habitats are important.

Little information on status, distribution, habitat requirement and impact of habitat degradation and fragmentation is known on different pheasant species of Kumaon. Taking into account the importance of species as well as conservation of area, this study was carried out in a hope to prepare a comprehensive conservation strategy for this bird group. Moreover the results obtained out of this study would also highlight the hotspot areas important in terms of pheasant species conservation. This study would come out with area specific problems for pheasant species conservation.

1.3 LITERATURE REVIEW

1.3.1 Overview of pheasant studies in Europe and America

Pheasants and human have long been closely associated dating back 5000 BC since Red junglefowl has been in domestication as the progenitor of the domestic fowl (Wood-Gush, 1959). William Beebe (1918-22) and Jean Delacour (1951 & 1977) made the first modern investigations in the mountains and jungles of Asia to gather information on pheasant species distribution. Their works on 'A monograph of Pheasants' (Beebe, 1922) and 'The Pheasant of the World' (Delacour, 1951 and 1977) are classics.

The Chinese Ring-necked pheasant *Phasianus colchicus* is the most common gamebirds and breeds in every county (Shorrock, 1976) in Britain. The Ring-necked pheasant was brought to Europe over 1,000 years ago from Asia Minor and later from China and Japan (Long, 1981), and today it is found throughout the Europe and USA. Introduction of this species in America was not successful in initial years, but by 1900 the species had spread over most of the parts in USA. The practice of stocking and hunting of pheasants as game became a common activity (McAtee, 1945). In Britain the bird is widely hunted for sport and to ensure high densities for shooting, birds are released from hand reared stock (Hill & Robertson, 1988a and Robertson & Dowell, 1990). The introduction of this species to various parts of Europe and America averted attention of avian ecologists. Almost all ecological and behavioral aspects of the Ring-necked pheasant have been covered and more than 600 references of published document is available on the species (Carroll, 1988).

1.3.1.1 *Habitat use and cover*

The workers like Gates & Hall (1964) using radio collar, studied distribution pattern of Wisconsin pheasants during winter. Habitat studies on this species by Guthery & Withesade (1984) revealed that Ring-necked pheasant used fringed wetland scrub in America when woodlands were absent. Robertson (1985) studied the winter habitat use of Common pheasant in Ireland. Seasonal variation in habitat use by Common pheasant was observed by Hill & Robertson (1988b). Gatti *et al.* (1989) studied habitat use and movement of female Ring-necked pheasant during fall and winter and found that the species preferred the food patches and brush and avoided pastures and croplands. Robertson *et al.* (1993) studied habitat factors responsible for Common pheasant density in UK.

Use of cover for various life-supporting activities was taken into account as a part of study conducted on Ring-necked pheasant. Warner (1979) studied use of cover by Ring-necked pheasant broods in east central Illinois and concluded that broods roosted mainly in oats and hay. Study conducted by Snyder (1984) on nesting ecology of the species in northeastern Colorado revealed that winter wheat and post harvest stable provided nesting habitat during spring season. Meyers *et al.* (1988), in their study on the use of cover types by Common pheasant observed that the survival of broods was related to cover types and in some cover types; survival was a function of age of the brood.

1.3.1.2 *Population studies*

Many workers have published their findings on the species on this aspect. Errington & Hammerstrom (1937) studied the nest loss and juvenile mortality of Ring-necked pheasant. Green (1938) observed the importance of food and cover relationship in the winter survival of pheasant in northern Iowa. Eklund (1942) studied the mortality factors affecting the nesting pheasant in the Williamette Valley while Bach (1944) studied the population fluctuation in North Dakota. Buss *et al.* (1952) assessed the significance of adult pheasant mortality in spring to autumn while Gondahl (1953) studied winter behavior of pheasant with relation to winter cover in Winnebago country. A comprehensive study on the species population ecology conducted between 1946-61 in

Wisconsin, revealed that high density of the species occurred in the areas with 50-70% cultivated land. Dumke & Pils (1973) used radio telemetry to study the mortality of pheasant and inferred maximum mortality during winter due to high rate of predation during the season. Gates & Hale (1974) in their study conducted on the reproduction of Ring-necked pheasant in central Wisconsin found harvesting operations to be responsible for the species mortality. Renesting dynamics of the species in Wisconsin was studied by Dumke & Pils (1979) and they observed that out of the disrupted nest, 68% renested and 71% of the second clutches were terminated, and also 41% of the females renested and produced 40% of the brood. Review on the population, ecology and distribution of pheasants in Illinois from 1900-1978 was documented by Warner (1981) and this large span of time comparison revealed that greater population were confined to high winter cover and more hay and small grain fields.

1.3.1.3 *Breeding*

Studies on this aspect have been conducted by workers (Goranson, 1980 and Trautman, 1982) and they found the Ring-necked pheasant to be a polygamous bird. Koubek & Kubista (1990) studied the daily activity pattern of lekking pheasant in Europe and observed that in southern Moravia (Czechoslovakia), male *P. colchicus* preferred territories with activity centers having cover while open fields were avoided. Ligon & Zwartjes (1995) observed the role of male plumage of Red junglefowl in female mate choice and found that though the plumage was not target of female's attraction but males with larger comb were.

1.3.1.4 *Feeding*

Scwartz & Scwartz (1951) studied the food of an isolated population of Ring-necked pheasant from 191 crops in Hawaiian Islands and recorded 152 food items from them. Hill (1985) studied the feeding ecology and survival of pheasant chicks on arable land and found arthropods to be the main diet of the chicks.

1.3.1.5 *Management*

Changes in landuse pattern due to various reasons adversely affected pheasant population as lower-harvesting results indicated. Robertson *et al.* (1988) surveyed butterfly number in a woodland in southern England and concluded that areas managed for pheasant population and butterfly species, recorded significantly higher in number than the unmanaged areas. Their studies also suggested that woodland management for pheasant survival could benefit many of the declining butterfly species. Robertson *et al.* (1993) studied affect of land use in breeding densities and the study suggested that new woodland planting and management could increase the breeding density.

1.3.2 Overview of pheasant studies in Asia

Studies on pheasants conducted in India have been described separately in this chapter. Not much work on distribution and ecology has been done in China, Nepal, Malaysia, India and Pakistan. Old records on pheasants came from British naturalists and sportsmen (Hodgson, 1846; Hume & Marshal, 1879 and Osmaston, 1935) as valuable information on general facts and habits of pheasants. The Work of Beebe (1918-22) 'A

Monograph of Pheasants' helped authors (Baker, 1935; Bates & Lother, 1952 and Ali & Ripley, 1987), after which they provided information on pheasants based on that book.

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1.3.2.1 *Status surveys and habitat studies*

Mirza *et al.* (1978) conducted surveys in Pakistan and recorded five pheasant species while Lelliot (1980-81) conducted studies for Cheer and indicated the presence of the species between the altitude range from 2200-2440m with low numbers. Duke (1989) conducted call count surveys in Pakistan Himalaya for density estimates of Western Tragopan and found that Palas valley had largest surviving population among the surveyed sites. Islam & Crawford (1987) studied the habitat use of Western Tragopan in Pakistan and found that the structural components of vegetation influenced the habitat use of the species rather than the plant forest types or plant associations. Studies on ecology of Chinese Monal *Lophophorus lhuysii* (Hen Fen-qi *et al.* 1988) indicated the presence of species in alpine scrub, subalpine, alpine pastures and exposed rocks and cliff Mountains. McGowan *et al.* (1991) studied habitat of Palawan peacock pheasant *Polyplectron emphanum* and found that human disturbance factor may be detrimental for the species survival in future. Severinghaus & Severinghaus (1989) studied the ecology and behavior of Mikado pheasant *Syrmaticus mikado* and Swinhoe's pheasant *Lophura swinhoe* in the Yushman NP (Taiwan) and found Swinhoe's pheasant between 1000-2000m altitude in temperate forest at gentle slopes while Mikado occurred between 1900-3800m altitude range in cold temperate zone in coniferous and mixed forest on steep slopes. Young *et al.* (1991) conducted studies on the ecology of Cobot's Tragopan *Tragopan coboti* and found that the species used areas with thick undergrowth having greater bare ground proportion near water resources at gentle slope. The species also used plant species *Daphniphyllum macropodium* as main part of their food items and roosting site. Bland & Han Lixiang (1993) studied the ecology of Lady of Amerest pheasant *Crysolophus amherstiae* in China while Li Xiang-tao (1993) studied Brown-eared pheasant *Crossoptilon mantchuricum* in Dongling mountain areas in China and he found the species to be associated with broad leaved and coniferous forest between 1300-2200m altitude range. In another study in China (Li Xiang-tao, 1995) the Brown-eared pheasant also inhabited 800-1800m altitude range. Differential habitat use by Cobot's Tragopan and Temminck's Tragopan *Tragopan temminckii* have been studied by Ding-Chang Quing & Zhang-Guang-mei (1993) and Shi Hai-tao *et al.* (1996).

1.3.2.2 *Population studies*

Several studies have been conducted on this aspect. Henn Fen-qi *et al.* (1988) studied density estimate of Chinese Monal. Zhang Junping & Zhang-Guang-mei (1989) conducted surveys in Wuyanling Nature Reserve in China to know the population structure and number of Cobot's Tragopan and found 7.1 birds per km^2 with equal sex ratio in the area. Li Xiangtao (1989) out of his study reported Temminck's Tragopan to be solitary or in family units of 2-5 birds during winter. Study of Islam & Crawford (1993) found male biased sex ratio in Western Tragopan in Pakistan.

1.3.2.3 *Breeding*

Zhang Guang-mei studied nesting ecology of Cobot's Tragopan and found that the bird nested in forest edges on trees of *Pinus taiwanensis* with clutch size range 2-6 eggs. Liu Xiaohua *et al.* (1989) studied breeding behavior of Hume's pheasant *Syrmaticus humiae* and found the breeding period between February- June and nests were found on the ground having dense cover. Zhao Zhengjie (1989) studied breeding ecology of the Ring-necked pheasant in China and found flocking in the species during autumn and winter while during spring and summer the species remained solitary or in pairs. Severinghaus & Severinghaus (1989) generally found Swinhoe's pheasant solitary but pair or family parties were observed during breeding season only. The status of Brown-eared pheasant in the Donling mountain (China) studied by Xiang-tao (1995) showed stable individual numbers with low density and poor breeding success due to high rate of egg predation by local people.

1.3.2.4 *Diet*

Studies in the wild on diet of the pheasants are few. Davison (1981) in his studies on the Crested-fireback pheasant in Malaysia observed majority of birds in moist areas with abundant invertebrates. Li Xiangtao & Lu Xiaoyi (1989) performed study on diet composition of Cobot's Tragopan and found the species to be vegetarian. Studies on Hume's pheasant (Liu Xiaohua *et al.* 1989) revealed the species to be ground forager and primarily vegetarian in diet. Zhao Zhengjiȇ (1989) in his study on Ring-necked pheasant found the species to be vegetarian in food habits and 83% food of the species was composed of plant materials.

1.3.3 Overview of pheasant studies in India

Few studies (Kaul, 1989; Sharma, 1990; Iqbal, 1992; Ahmed, 1995; Yasmin, 1995 and Khaling, 1998) conducted detailed species account in India. However, numerous and short-term studies on various aspects of behavior ecology and distribution of pheasants have been conducted from time to time. Collias & Collias (1967) conducted one of the first studies on pheasants in India near Dehra Dun on the vocalization of Red junglefowl and found that crowing was used by the dominant male to advertise territorial right and asserted dominance. Bland (1980) reported first record of Western Tragopan in UP nearly 20 years ago while he found plentiful Koklass in Himachal Pradesh. Gaston & Singh (1980) surveyed Chail sanctuary and reported presence of Cheer. Lamba *et al.* (1982) reported Koklass and Himalayan Monal but they did not report Western Tragopan and Cheer from the area. Gaston *et al.* (1983a) carried out surveys in the years 1979 and 1980 in Himachal Pradesh and reported seven pheasant species and proximate threat factors for the reported species. In another study carried out in Himachal Pradesh, Gaston *et al.* (1983b) reported Cheer, Himalayan Monal, Koklass and Western Tragopan from the area. Kaul (1986) conducted surveys in Limber valley in Kashmir and reported presence of Western Tragopan population from one of the surveyed sites. Young & Kaul (1987a) conducted surveys in Kumaon Himalaya to document status and habitats of different pheasant species and they reported Kalij, Koklass, Monal, Satyr and Cheer to be present in the area. Young *et al.* (1987b) studied calling behavior of Cheer in Kumaon. Bisht *et al.* (1989) performed studies on habitat utilization of Monal pheasant in Kedarnath WLS and found the species to be in good number in the areas having substantial human population. Chandola-Saklani *et al.* (1989) investigated some behavioral traits and seasonal movement of Whitecrested Kalij in Garhwal Himalaya and documented that female birds showed greater foraging activity and declined feeding rate during breeding season. Ahmed & Musavi (1993) estimated the density of Whitecrested Kalij at Ranikhet in Kumaon and reported five birds / km^2 from the area.

Iqbal (1993) studied the pattern of habitat use of Whitecrested Kalij at two sites in the Indian Himalayas. Garson *et al.* (1992) conducted studies for ecology and conservation of the Cheer pheasant in Kumaon Himalaya. Kalsi (1993) studied habitat preference of Red junglefowl in Kaleshwer Reserve Forest in Haryana and found that the species preferred mixed forest with cultivation to sal and mixed forest. Pandey (1993) conducted surveys in Himachal Pradesh and reported 10 new Cheer sites, nine Kalij sites and six Monal and Koklass sites. He also reported Western Tragopan, Red junglefowl and Peafowl from two sites. Pandey (1993-94) in his preliminary surveys on Western Tragopan in Daranghati sanctuary in Himachal Pradesh recorded 1.5 birds/km^2 during winter. Sathyakumar *et al.* (1993) studied density estimate and habitat use of Kalij and Monal pheasants in Kedarnath WLS and found 16-17 pairs of Kalij per km^2 and 10-16 pairs of Monal per km^2. They also found Kalij to be distributed between 1600-2000m altitude range and for Monal it was between 2600-3300m. Narang (1993) conducted surveys and reported six localities having Western Tragopan in Himachal Pradesh. Satyanarayana (1992) described the roosting tree species used by Peafowl. Sharma & Chandola-Saklani (1993) monitored different populations of Whitecrested Kalij in Garhwal Himalaya and reported the months March-July to be the breeding season of the species in the area. Yasmin (1995) studied the roosting behavior of Peafowl in UP in India. Hussain *et al.* (1997) conducted surveys in Kumaon Himalaya and reported five pheasant species. Ghosh (1997) studied the ecology of Blyth's Tragopan in Mizoram state of India and came out with the results of habitat occupancy by the species and various threats as limiting factors for the survival of the species. Kumar *et al.* (1997) studied winter habitat use by Monal pheasant in Kedarnath WLS and found preference of different habitat types by the species during different seasons of the year. Khaling (1998) conducted surveys in Singhalila NP, Darjeeling, and estimated density of Satyr Tragopan by using call count method during spring and reported mean density of 6.19 individuals per km^2 from the area. Hussain *et al.* (2001) studied some aspects of ecology of Kalij and Koklass in Kumaon Himalaya and found altitude to be the main discriminating factor in the distribution of these species. Moreover, the Kalij abundance was positively correlated with shrub diversity, herb density and livestock population and in case of Koklass, altitude, grass richness, herb diversity and herb richness were positively correlated with abundance.

In Kumaon Himalaya current status and ecological information on pheasants was lacking. Therefore, this study was carried to fulfill the gap in information for this bird group. This study was part of the long-term ecological project titled "A study of threats to biodiversity conservation of the middle altitude oak forest of Kumaon Himalaya, India" funded by the Ministry of Environment & Forests, Govt. of India.

1.4 OBJECTIVES

The main objectives of this study are,

1. To study the status and abundance of different pheasant species of Kumaon Himalaya.
2. To study various ecological aspects of different pheasant species of Kumaon.
3. To study social organization of different pheasant species of Kumaon.

4. To assess various threats upon different pheasant species as well as surveyed localities in Kumaon Himalaya.
5. To prepare a conservation strategy for each pheasant species and to suggest recommendation for their management and conservation.

1.5 ORGANIZATION OF THESIS

Chapter 1

This chapter deals with general introduction of pheasants. It also accounts the past work done on pheasants in various parts of the world including India and Kumaon. Objectives have also been described in it.

Chapter 2

This chapter describes about the study area i.e. Kumaon Himalaya. Historical account of forest cover of Kumaon Himalaya has also been included as a part of this chapter.

Chapter 3

This chapter specifically deals with the vegetation of the Kumaon Himalaya. Dominant communities of trees and ground vegetation have been extracted and described. GIS and spatial analysis for different vegetation parameters is performed in this chapter. Spatial parameters have also been calculated to define fragmented oak patches of Kumaon.

Chapter 4

This chapter deals with current status and distribution of different pheasant species found in Kumaon. Abundance in terms of encounter rate has been calculated for each species. Abundance predictors for Kalij and Koklass in terms of habitat variables and threat factors have also been taken into account.

Chapter 5

This chapter deals with how different pheasant species of Kumaon are ecologically separated from each other in their distribution range in Kumaon. It also describes habitat utilization at micro & macro level by different pheasant species in different seasons of the year.

Chapter 6

It deals with results obtained from feacal matter analysis for diet composition (plant and animal matter) of different pheasant species. Seasonal variation in diet composition has also been attempted in this chapter. References slides of 40 plant species were prepared. Out of these 36 plant species were found in the droppings of studied pheasant species.

Chapter 7

It describes group size and group composition of different pheasant species of Kumaon. Attempts have also been made to observe seasonal variation in group size and group structure of different pheasant species. Sex ratio for each species has also been calculated.

Chapter 8

The theme of this chapter is to evaluate various localities on the basis of abiotic and biotic pressures. This chapter also deals with assigned conservation value to each locality on the basis of conservation of different pheasant species of Kumaon. The chapter also describes about evolved conservation strategies and recommendations for the conservation of different pheasant species of Kumaon.

CHAPTER 2

STUDY AREA

2.1 INTRODUCTION

Himalayas, the major geomorphologic or tectonic division of the Indian subcontinent, constitute one of the great and young fold mountain systems in the world. It rises from 300m to more than 8000m above the msl. Extending from the eastern border of Pakistan to the western frontiers of Burma and having a length of about 24,000 km, and a width varying from 250-400km, it covers an area of about 5,00,000 km^2.

The Planning Commission (1982), Govt. of India, has divided the Himalayas lying in India into three broad regions; the Western Himalaya consisting the states of Jammu & Kashmir and Himachal Pradesh, the Central Himalaya consisting 10 hill districts of Uttaranchal and the northeastern Himalaya comprising the states of Sikkim, Manipur, Meghalaya, Tripura, Arunachal Pradesh and Mizoram and the hill areas of Assam and West Bengal. From south to north, the Himalayas are divided into four geophysical divisions, the outer Himalaya, the lesser Himalaya, the Great Himalaya and the Trans Himalaya. These longitudinal divisions are separated from one another by several thrusts such as Himalayan Front Fault (HFF), Main Boundary Thrust (MBT), Main Central Thrust (MCT) and Tons Himadri Thrust (THT) (Burrard *et al*, 1933; Kharakwal, 1951; Jalal, 1976; 1988 and Valdiya, 1980; 1988).

2.2 HISTORICAL BACKGROUND OF KUMAON HIMALAYA

Historically, Kumaon Himalaya was part of Oudh Province. Gorkhas ruled Kumaon before the British annexed the area in 1815. Thus, from 1815 to 1947 A.D., the area remained under British colonial rule. During the British period this area was declared as "Non-Regulated Area", hence the rules and regulations implemented here were quite different from those of plains (Mittal, 1990).

Very little is known about agricultural condition and its development during 19th century. Kumaon from ancient times seems to have been agricultural area (Pate Ram, 1916) but practicing it was a difficult job. For this, there were factors like occasional floods, hailstorms, landslides, the ravages of wild animals and a high degree of mortality among both the people and the cattle were some of the obstacles which made the cultivation in the hills difficult. It was observed and written by Sample (1921) during British period that sustenance was very severe, yet, agriculture flourished well till the beginning of 19th century.

Great decline in agricultural practices was observed on account of the barbarous rule of Gorkhas (1790-1815 A.D). After the British took control in 1815, from 1816-1823 cultivation had increased one third and since then there was steady progress (Kennedy, 1884). The net cultivable area in the Kumaon during 1842-1846 was 10.08% of total area of Kumaon which was further increased up to 15.61% during the years 1872-1873, and it was further extended to 17.06% in the year 1886 (Mittal, 1990). The cultivable area increased up to 25.28% of the total area of Kumaon in the year 1978.

A steady increase in agricultural land was observed through out the Kumaon. This increase was due to increase in human population. An increase of 12.8% in the agricultural production was observed due to the policy of encouragement by the commissioner of Kumaon within twenty years from 1815-1835 (Pant, 1935). The region has recorded increase in total human population from 1,64,000 to 8,07,213 individuals (Joshi *et al.*, 1983) during the years 1821-1921 and the human population further increased from 8,60,588 to 29,43,199 individuals during the years 1931-1991 (Table 2.1).

Table 2.1 Changes in the human population during 19th and 20th century in Kumaon Himalaya.

Year	Human population
1821	1,64,000
1852	3,60,011
1881	7,01,007
1911	8,49,149
1941	9,79,147
1971	19,55,281
1991	29,43,199

Industrialization, agricultural expansion and development of the area in terms of road establishment degraded the forest area. The contract arrangement for felling trees continued until the 1858 and as a consequence no conservation measures could be introduced. Between 1855 to 1861, due to tremendous demand of railway sleepers, uncontrolled felling of Sal trees was attempted in the more accessible forests. The increased human population from 1,64,000 in 1821 (Atkinson, 1986) to 777,600 in 1900 (Joshi *et al.* 1983) exerted more pressure on oak forest because they provided them cheap fuel, leafage, fodder, and Sal and Deodar tree species provided wood for timber and agricultural implements. The reckless destruction of valuable forests in the quest of railway sleepers and exploitation for other human needs enhanced the national timber resource. Ramsay, the first conservator of forest, recognized the gravity of the situation and he took immediate measures to stop this wanton destruction of forests, and from this time forests progressed with vigor.

The forest department in this region was organized for the first time in 1868 with a conservator of forest as its head. For several decades forest department remained engaged more in conservation than exploitation. And this essential conservation effort, which was the keynote of the forest administration, then created a sufficient discontent among people of Kumaon (Pant, 1921). There was a widespread feeling of discontent and the forest policy of the government was criticized and condemned all over the area. In 1917, a fresh settlement was made which divided forests into the following categories,

a) Reserved forests (old reserves & new reserves)

b) Protected forests or civil forests

Recent assessment showed that 25.28% (Joshi *et al.*, 1983) of total area of the Kumaon was under cultivation in the year 1978. Total forest cover which was 44.3% in 1972 (Singh, 1983) of the reporting area (18631.80 km^2) of Kumaon has increased up to 48.4% in the year 1979-80 (Joshi *et al.*, 1983). The recent forest cover of Kumaon was 35.61% (Anonymous, 1991) in the year 1991. Drastic decrease in the forest cover was observed in whole of Kumaon after independence.

2.3 LOCATION AND AREA

The study was conducted in the five districts; Almora, Bageshwer, Champawat, Naini Tal and Pithoragarh of Kumaon Himalaya (28° 43' 55" and 30° 30' 12" N latitude and 78° 44' 30" and 80° 45' E longitude) covering an area of 21032 km² of Uttaranchal hills in India. Tibet bound the area in north, Nepal in east and Tarai region of U.P. in south. 23 oak patches, varying in sizes at different locations of Kumaon Himalaya were covered during the study period (Fig. 2.1). Table 2.2 provides the details of sites covered during the entire study period (January 1996-December 1998).

About 90% of the area of Kumaon is mountainous. The main ranges are aligned in NW-SE direction. The asymmetrical slopes, i.e. steeper along the southern and gentler along the northern aspects form the characteristic features of the region. The Kali, Dhauli Ganga, Gori Ganga, Saryu and Pindar form the major river system of Kumaon. Later, only Pindar, Kali and Saryu form the major river system of the region. On the basis of physiographic attributes such as absolute and relative relief, the region may be grouped into the following physiographic regions

Himadri (Greater Himalayas)

Shiwalik and lesser Himalayas

Outer Himalayas – Tarai and bhabhar Himalayas

2.4 PHYSICAL SETTINGS

The Himadri (greater Himalayan) zone is about 50 km in width. The mean relief averages between 4800-6000m consisting of peaks covered with snow throughout the year. The valley profile shows concave form with steep valley wall with rising phase of Himalayas (Singh, 1987).

The lower Himalayas with a width of 75 km is composed of massive mountainous tract. The ranges are mainly composed of highly compressed and altered rocks varying in age. The average relief of ridges in this zone ranges between 1500-2700m and the valley bottom 500-1200m. The valleys are steep. The bhabhar belt, a piedmont plain 10-15 km in width, is the immediate land composed of debris from the Himalayas. The surface streams disappear in this zone of boulders and sand.

The lake region of Kumaon has its own characteristic features. These lake basin roughly confined to a belt of approximately 25 km in length and four km in width near the outer fringes of the lesser Himalayas in Naini Tal, Bhim Tal, Naukuchiya Tal, Sat Tal and Puna Tal form a group of lakes to the east of Naini Tal and form considerably low lying lake basin. Another group of lakes; Sukha Tal, Kurpa Tal and Saria Tal are very small in their size.

2.5 SOIL

So far, no systematic and detailed study has been made about soil of the Himalayas. The soils of this region do not form a compact block. They differ from valley to valley and slope to slope according to the different ecological condition. The humid-tropical vegetal zone (300-900m) is composed of 'alluvial soil', warm temperate-zone (900-1800m) has 'brown forest soil', and the cool temperate-zone (1800-3000m) is composed of brown deciduous soil and grey coniferous soil. Alpine zone (3000-4500m) soils are mostly granitic sandy loam. These soils are normally loamy but clay increases in

Fig. 2.1 Location of surveyed oak forest patches in Kumaun Himalaya.

Table 2.2 Details of different surveyed sites of Kumaon Himalaya. RF = reserve forest, POF = privately owned forest, WS= Wildlife sanctuary, CF = Community forest. * = Intensive study area

Sites	District	Area (km^2)	Status	Coordinates	
1. Kilbery	Naini Tal	16.25	RF	29°25' 24.3"N	79°2.6'24.3"E
2. Vinaiyak*	Naini Tal	15.32	RF	29°27'45.4"N	79°24'31.8"E
3. Kunjakhrarak	Naini Tal	14.50	RF	29°39' N	79°18'58.1"E
4. Maheshkhan	Naini Tal	22.00	RF	29°24'16.2"N	79°33'50.6"E
5. Gager	Naini Tal	3.25	RF	29°25'11.4"N	79°30'31.9"E
6. Mukteshwar	Naini Tal	15.75	RF	29°28'34.1"N	79°38'28.1"E
7. Jilling	Naini Tal	2.50	POF	29°22'1.6"N	79°37' E
8. Binsar WLS*	Bageshwer	11.25	WS	29°42'3.2"N	79°45' E
9. Pandavkholi	Almora	13.23	CF	29°48'19.5"N	79°27' E
10. Sitlakhet	Almora	11.25	RF	29°42'3.2"N	79°45' E
11. Jageshwer	Almora	21.00	RF	29°39'3.2"N	79°50'52.5"E
12. Gasi	Bageshwer	49.50	RF	30°04'48.4"N	80° E
13. Dhakuri	Bageshwer	32.50	RF	30°13'19.5"N	79°55'26.3"E
14. Wachham	Bageshwer	11.00	RF	30°07'25"N	79°54'37.5"E
15. Sunderdunga	Bageshwer	25.75	RF	30°13'30.3"N	79°54'18.5"E
16. Pindari	Bageshwer	21.50	CF	30°11'11.3"N	79°59'30"E
17. Daphiadhura	Pithoragarh	34.36	WS	Not available	
18. Majtham	Pithoragarh	25.00	WS	Not available	
19. Gandhura	Pithoragarh	54.00	WS	29°51'40"N	80°14'16.9"E
20. Sobala	Pithoragarh	28.12	WS	30°04'16.2"N	80°34'15"E
21. Duku	Pithoragarh	52.00	WS	30°56.3' N	80°30' E
22. Munsiary	Pithoragarh	30.50	RF	30°05'3.2"N	80°14'41.3"E
23. Mechh	Champawat	23.25	CF	29°16'16.2"N	80°12'18.8"E

the subsoil layers (Makhan, 1967). These soils are not suitable for crops other than potato cultivation and horticulture.

2.6 CLIMATE

Extreme variation in the climatic condition is observed in the entire region of Kumaon. The range of altitude of the region's mountainous topography influences its climate. Owing to its complicated relief, microclimates are of considerable importance. Valleys of the region experience hot steamy tropical climate during summer, while great ranges bear some of the highest snowfields of the world. Winds in narrow valleys and heavy fog during winter in wide valleys are conspicuous features of the weather of this region. The precipitation of every locality is directly related not only to the altitudinal zone in which it exists but also to its situation in the front ridge or the rear of the ridge or overlapping spur. When the study was conducted in the Kumaon, there were only three districts but two more districts (Bageshwer and Chmpawat) have been carved from Almora and Pithoragarh so the meteorological data were recorded for three districts only, which include information for newly, formed districts also (Fig. 2.2).

The monsoon starts at the end of June and ceases by the middle of September (Singh, 1987). Conventional rain in small amounts (12-25 mm) is observed every third and fourth day often in the afternoon just before the break of monsoon at higher elevation. The zone between 1200-2100m receives maximum precipitation (3267 mm) in both the seasons (summer and winter). The zone above 2400m experiences much lesser amount of summer rainfall. There are marked differences in the amount of rainfall in the front and rear of the main range. The rainfall of the region averages 370-500 mm from

June to September in the front zone, and 200-250 mm in the rear (Table 2.3). In general, winter depression causes snowfall for seven to eight days in each of the three months from January to March. April and May are marked by thunder and occasional hail storms and heavy snowfall up to 3-5 m is observed from November to May (Fig. 2.3)

The microclimatic condition usually differ from valley to valley and from locality to locality according to the direction of ridges, degree of slope, sunny or shady aspects of slope, intensity of forest cover and nearness to glaciers. The region can be divided into seven broad climatic zones, primarily based on altitude (Saxena *et. al.* 1985 and Singh, 1987) (Table 2.3).

2.7 NATURAL VEGETATION

A major part of the region is covered with forest constituting enormous wealth. About 35.61% area is under forest cover (Anonymous, 1991). According to Champion & Seth (1968), the vegetation of the area has been divided into four main zones. Sub tropical zone (below 1200m), extending from northwest to southeast, cover sub Himalayan tract of the region. Sal (*Shorea robusta*) is the main tree species. *Shorea* forests are seen on the Shiwalik up to an altitude of 1200m. The other associated tree species of this zone are *Largerstroemia parviflora, Dalbergia sissoo, Anogeissus latifolia, Terminalia* sp., and others. The canebrakes and bamboo brakes (*Dendrocalamus strictus*) are also found in the wet hollows and along the stream.

The temperate forests are generally found between 1050-1900m altitude range on the southern and 900-1800m on the northern slope. The chir pine (*Pinus roxburghii*) forms excellent forest at an altitude above 1200m often reaching to an altitude of more

Table 2.3 Mean temperature and rainfall in different climatic zones of Kumaon Himalaya (Singh, 1987).

Climatic zone	Altitude range (meter)	Temperature (° C)		Rainfall (mm)
		Mean	Annual	(Annual mean)
Tropical zone	300-900	18.9	21.1	2860.33
Warm temperate zone	900-1800	13.9	18.9	3623.33
Cool temperate zone	1800-2400	10.3	13.9	1750.00
Cold zone	2400-3000	4.5	10.4	335.00
Alpine zone	3000-4000	3.0	4.5	-
Glacier zone	4000-4800	Ten months below zero Two months between 2.2 and 3.9		-
Perpetually frozen zone	> 4800	Cold desert-no vegetation		-

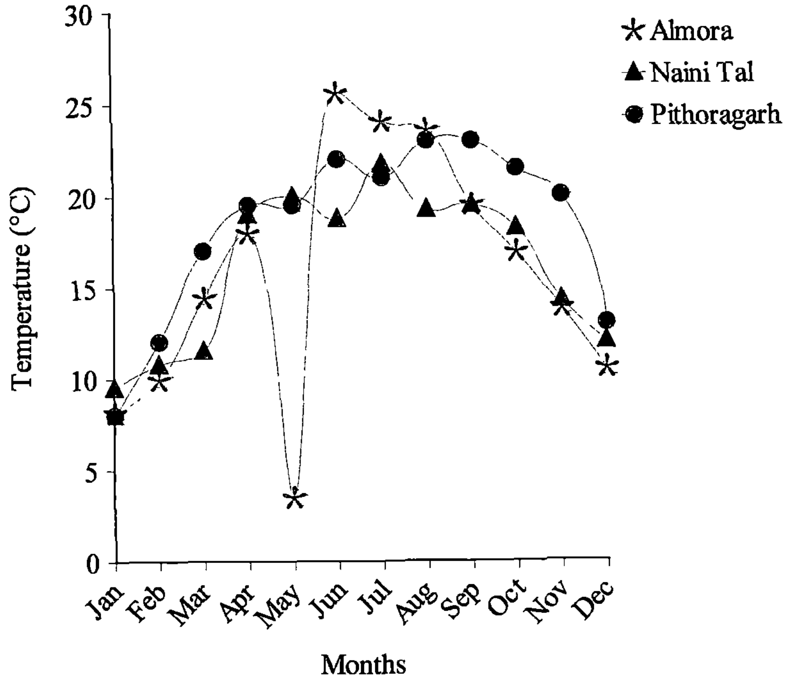


Fig. 2.2 Mean monthly variation in temperature in three districts of Kumaon Himalaya during 1998 .

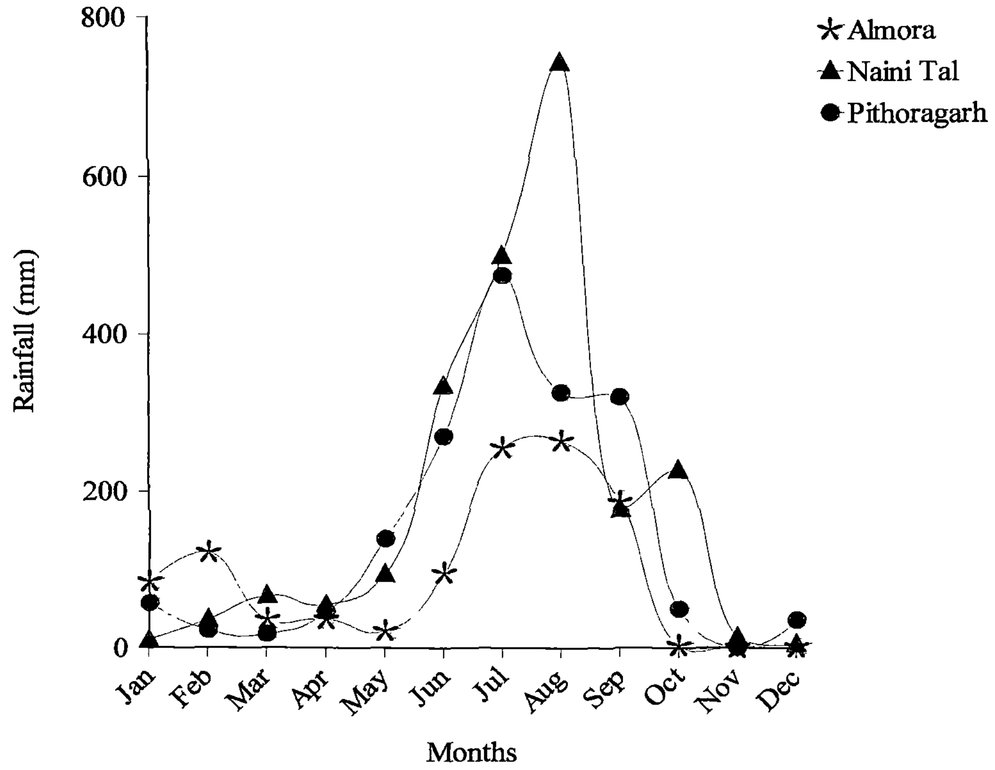


Fig. 2.3 Mean monthly variation in rainfall (mm) in three districts of Kumaon Himalaya during 1998.

than 2000m. The under growth of pine is very poor. Some species of deciduous forests are observed occasionally, otherwise the ground surface is covered with various species of grasses. At its upper limit, the pine may occur in association with *Quercus leucotricophora* and *Rhododendron arboreum*. The Oak-Rhododendron forests in association with *Lyonia ovalifolia* are found at altitude above 1500m in the areas having sufficient soil moisture on the northern exposure and sheltered slopes. Oak-Rhododendron forests are densely populated and rich in epiphytes. At slightly higher elevations between 2200-2800m *Quercus leucotricophora* is replaced by *Quercus floribunda* with the same tree species association as those seen with the *Quercus leucotricophora* forest. At altitude above 2800m, another Oak-Coniferous forests occur, in which dominant tree species are *Quercus semecarpifolia, Abies pindrow* along with *Rhododendron arboreum, Taxus baccata, Pinus wallichiana, Euonymus tingens, Viburnum* sp., *Cupressus torulosa, Cedrus deodara* and *Betula utilis* etc.

In general, each forest cover occupies some definite locality; between 2000m and 3000m cypress is present, from 2400–3000m Deodar, from 1900-3100m blue pine and silver fir. The high level forest are usually found in the traits lying to the north of the main Himalayan ranges between 2950-3600m, covering the sub alpine and alpine zone. Above the birch and silver fir forests, a general transition from xerophytic bush land into alpine pastures. These alpine forests are found up to about 4200m and sometimes may be seen in small patches even above. The alpine pastures are the main vegetal cover on the high altitudes (Singh, 1987).

2.8 FAUNA

The Kumaon Himalaya holds rich oriental faunal composition (Mani, 1974). The area still holds some of the rare, endangered mammal and bird species. The main mammal species of the region are Musk deer *Moschus moschiferus* (endangered), Himalayan Tahr *Hemitragus jemlahicus* (suspected to be endangered), Serow *Capricornis sumatraensis* (possibly endangered), Himalayan black bear *Selenarctos thibetanus*, Goral *Nemorhaedus goral*, Barking deer *Muntiacus muntjak*, Yellow-throated martin *Martes flavigula*, Leopard *Panthera pardus* and Snow leopard *Panthera uncia* (endangered). Among birds, the area includes conspicuous species like Cheer pheasant *Catreus wallichii* (globally threatened), Satyr Tragopan *Tragopan satyra*, Monal pheasant *Lophophorus impejanus*, Koklass *Pucrasia macrolopha*, Whitecrested Kalij *Lophura leucomelana*, White-throated tit *Aegithalos niveogularis* (endangered), Pied thrush *Zoothera wardii* (endemic), White-crested laughing thrush *Garrulax leucolophus*, Red-billed chough *Pyrrhocorax pyrrhocorax*, and many species of finches, raptors, woodpeckers, laughing thrushes, tits, leaf warblers and flycatchers. Among reptiles, Python *Python molurus*, Common Indian krait *Bungarus caeruleus*, Indian cobra *Naja naja*, Rat snake *Elaphe obsoleta*, the Himalayan pit viper *Ancistrodon himalayanus*, Common Indian monitor lizard *Varanus varanus* and Common house gecko are common. Among butterflies the notable species are Indian cabbage *Pieris canidia indica*, Common sailor *Neptis hylas varmona*, Painted lady *Cynthia cardui*, Common tiger *Danaus genutia*, Great Mormon *Princeps memnon agenor*, Common Mormon *Princeps polytes romulus*, Common blue bottle *Graphium sarpedon sarpedon*, Indian tortoiseshell *Aglais* *cachmirensis aesis*, Paris peacock *Princeps paris paris* and Oak leaf *Kallima inachus inachus*.

CHAPTER 3

VEGETATION STUDIES

3.1 INTRODUCTION

Vegetation is one of the major geographical features of almost all parts of the earth's surface. In the major natural ecosystem, at least, it is an essential component as it attains the status of primary producer. Nevertheless, the structure of vegetation is not a mere show of the general dominance by certain species it also exhibits local dominance by other species (Weaner & Clements, 1966).

Himalayas, the youngest mountain system of the world, constitute an important link and/or bridge between the vegetation of the north-western and western Asiatic-European areas, and the southern peninsular India on one hand and the eastern Malaysian and the north-eastern Sino-Japanese and the northern Tibetan areas on the other (Puri *et al.* 1983). Phytogeographically, it is therefore one of the most complex areas of the Indian subcontinent. In some way they act as a bridge between the Sino-Japanese and the Irano-Turanian regions; the two most important centres of the Holarctic or extra- tropical Eurasian flora. Stearn (1960), Raven (1962) and Meusel (1971) have studied the western Himalayan flora and vegetation from this angle.

The Himalayan Mountains from Kumaon to Kashmir are with considerable variation between the outer and the inner valleys. The vegetation is divided into altitudinal zones, such as sub-montane zone up to about 1500m, a Temperate Zone from 1500m to 3300m or 3630m, and an alpine zone above the snowline. The altitudinal zonation of different types of vegetation is not restricted and it has been found that geology and soils exercise a far greater influence on the distribution of vegetation types than altitude or climate (Puri *et al.* 1983). The other important feature in the Himalayas is the role of man in delimiting the vegetation zones.

Now the question arises that why should we study vegetation. The commonest examples of the use of vegetation description are in the recognition and definition of different vegetation types and plant communities, the mapping of vegetation communities and types, the study of relationships between plant species distributions and environmental controls, and the study of vegetation as a habitat for birds, mammals and insects. Information on vegetation may be required to help to solve an ecological problem: for biological conservation and management purposes, as an input to environmental impact statements; to monitor management practices or to provide the basis for prediction of possible future changes.

A useful study is applied studies where vegetation data are collected and analyzed with the aims of providing information of relevance to some ecological problem, often to do with environmental conservation and ecosystem management. The forest resources of the country are under great pressure owing to the increased demands from human and animal population resulting in degradation of forest ecosystems. This has led to poor productivity and regenerative capacity. Hence monitoring of our forest resources is of great importance (MOE&F, 1994; FAO, 1995; FAO, 1993 and MOE&F, 1997). However, various other aspects related to efficient forest management through advanced tools like Geographic Information System (GIS) is minimal and not comprehensively studied at the scale required for initiation of actions (Udya Lakshmi *et al.* 1998). The collection and organization of existing scattered information with a provision to synthesize and update without much additional effort is needed for optimal resources management (Mukund Rao *et al.* 1994; Mukund Rao & Jayaraman, 1995 and Rajan, 1991). Similar capabilities are possible only through use of advanced technological tools, viz. Remote Sensing (RS) and GIS (Karale, 1992 and Rao, 1995).

In the proposed study, I tried to collect ground truth data of Kumaon and map on spatial scale and also in relation to pheasants. The approach used in this study was to concentrate efforts in obtaining i) assessment of flora and fauna, ii) identifying the threatened area, iii) finding the relationship between fauna and environmental data, iv) relationship between fauna and threats. In the final and concluding stage, prioritise areas for long-term conservation is suggested.

The objectives of this chapter are-

1. To describe the density, diversity and richness of all the vegetation layers i.e. trees, shrubs and ground layer for all the surveyed sites of Kumaon.
2. To observe the correlation between vegetation attributes and altitude and also with biotic pressure.
3. To describe different dominating communities of trees, shrubs and ground vegetation of Kumaon.
4. To find out most fragmented patches with the help of GIS.
5. To find out the plant species of special concern and also the localities having rare plant communities for protection.

3.2 METHODOLOGY

Fieldwork for this study was carried out from March 1996 to December 1998 in Kumaon Himalaya. Overall 902 sampling plots were laid in all 23 oak patches (details in Table 3.1). Vegetation was sampled on the transects on set bearings and on the existing forest trails. The trails and transects passed through all the major habitat types at each site to allow sampling of different habitats in equal proportion. Three transects of one km each, were laid only in Binsar Wildlife Sanctuary (BWS) while trails were sampled in all oak patches including BWS (Fig. 3.1). Each transect was divided into 20 points, each 50m apart. Sampling points, each 50m apart on trails, were taken on either side of the trail to avoid sampling the relatively disturbed vegetation along it.

Circular plot method following Dombois & Ellenberg (1974) was used for vegetation sampling. At each sampling point, a 10m radius circular plot was established. Trees of > 4m height were considered as mature trees and different species and their individuals were recorded for the estimation of density, species diversity and species richness. Shrub layer was quantified in 3m radius circular plot with in the existing 10m radius-sampling plot. Shrub species and their numbers were recorded for the estimation of density, diversity and species richness. Ground vegetation (herbs and grasses) was estimated in 0.5m x 0.5m quadrate at four places within the 10m radius circular plot. The species and their numbers were recorded for the estimation of density, diversity and species richness.

Tree cover was measured by using gridded mirror of 10 x 10 inches dimension, divided into 25 equal grids. The mirror was placed horizontally at 1.25m above the ground touching the body of the observer. Tree cover was measured at 5m distance from

Table 3.1 Distribution of sampling points in different oak patches of Kumaon Himalaya.

Oak patch	Number of sampling plots	Altitude range (m)
Kilbery	40	2085- 2240
Vinaiyak	40	2130- 2290
Kunjakharak	45	2040- 2430
Maheshkhan	40	1820- 2090
Gager	40	1860- 2220
Mukteshwer	49	1800- 2260
Jilling	20	1860- 2010
Binsar	75	1990- 2260
Pandavkholi	40	2460- 2590
Sitlakhet	15	1880- 1980
Jageshwer	26	2060- 2200
Gasi	40	2140- 2370
Dhakuri	55	2470- 2825
Wachham	50	2410- 2935
Sunderdunga	36	2560- 2780
Pindari	39	2200- 2960
Daphiadura	40	2020- 2440
Majtham	40	1595- 2250
Gandhura	50	1710- 2045
Sobala	40	2190- 2650
Duku	48	1930- 2530
Munsiary	25	2655- 2770
Mechh	10	1810- 1830

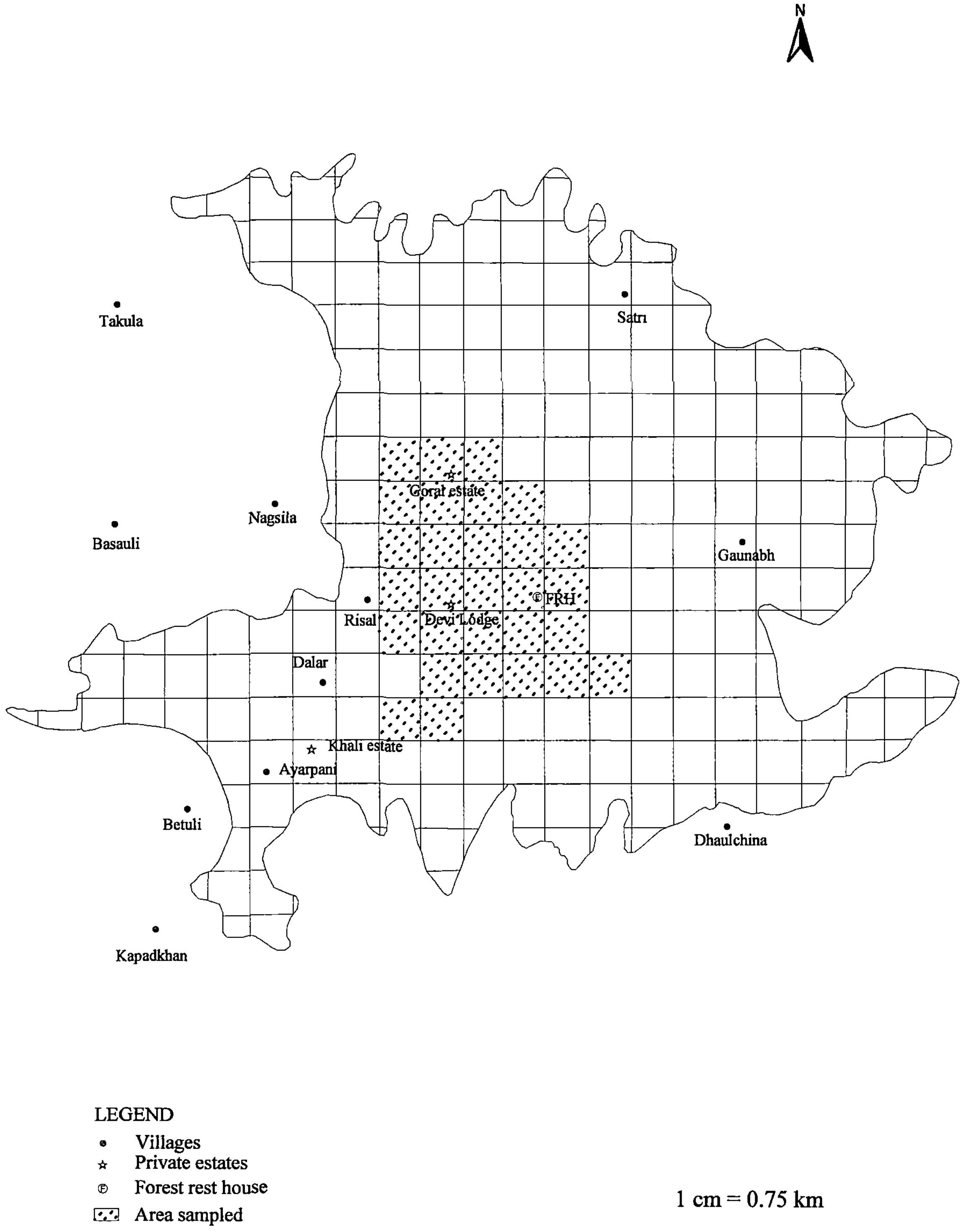


Fig. 3.1 Area sampled for biodiversity evaluation in Binsar Wildlife Sanctuary.

the sampling point in four different directions. Grids covered with more than 50% foliage were counted and expressed in terms of percent tree cover.

3.2.1 GIS approach

The outer boundary of Kumaon region and its districts were digitized from toposheets published by Survey of India. All 23 oak patches were also carved from 1:50,000 scale toposheets published by the Survey of India (Reference No. 53-O/7, 53-O/10, 53-N/16, 53-O/14, 53-O/11, 62-B/4, 62-B/8, 62-B/12, 62-C/1 and 62-C/3). The whole map with oak patches was digitized by Auto Cad R-14 computer software program. Outer boundary, districts boundaries and patch boundary were digitized as separate layers and polylines were converted into polygons by program Data Automation Kit (DAK). Each oak patch was considered as one polygon.

The area of proposed sanctuaries was also carved from 1:50,000-scale toposheet. The map was divided into grids of 1 x 1 km. On ground, the data on different aspects were collected for each grid. GIS analyses were conducted by ArcView 3.2 software program. Data were imported through dbase file format. Thematic maps were prepared by considering some aspects such as tree cover (Fig. 3.2), tree density (Fig. 3.3), tree diversity (Fig. 3.4) and shrub diversity (Fig. 3.5). Combinations of thematic maps were also overlaid. Query analysis was performed on the map of Binsar Wildlife Sanctuary.

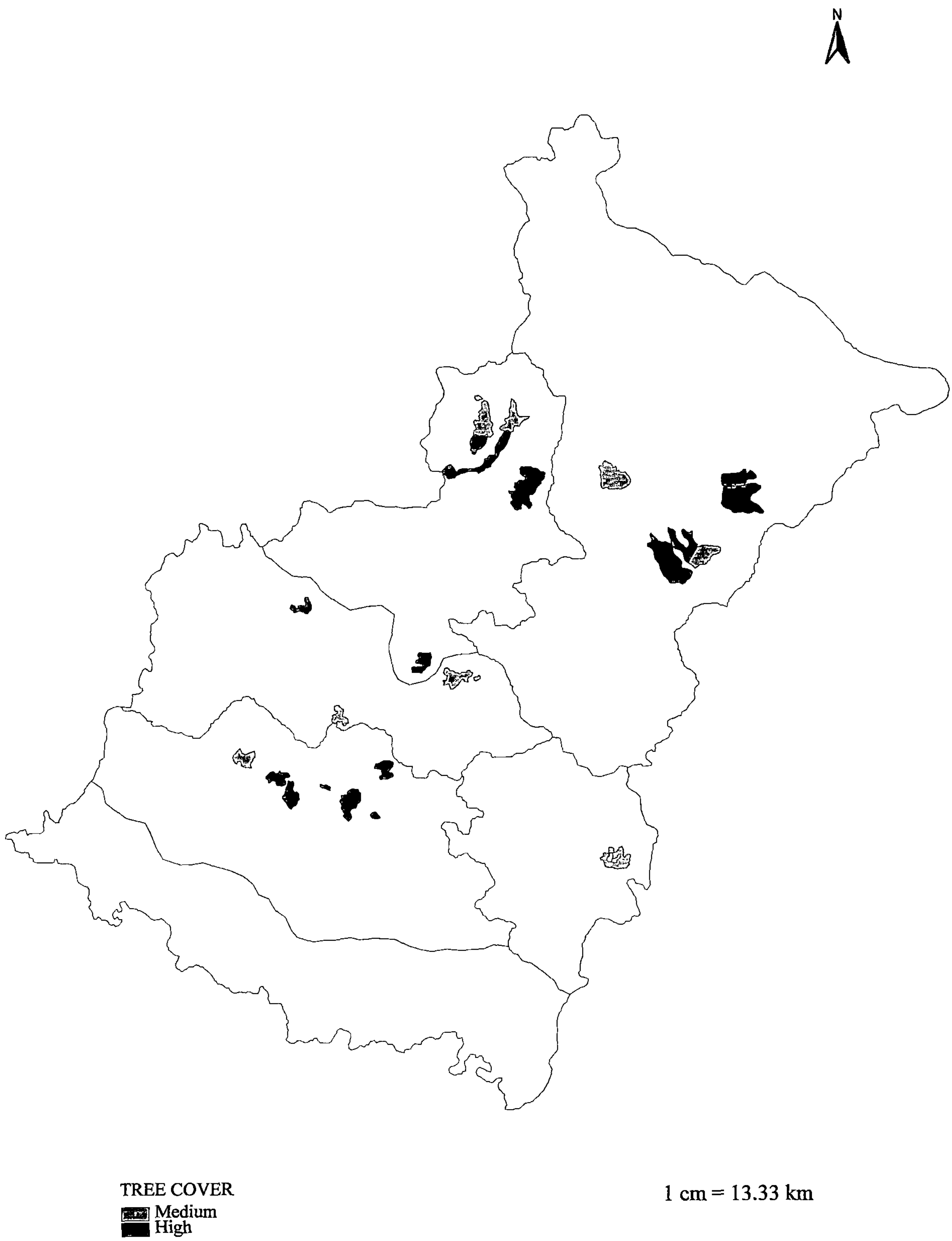


Fig. 3.2 Extent of tree cover in oak forest patches in Kumaon Himalaya.

Fig. 3.3 Extent of tree density in oak forest patches in Kumaon Himalaya.

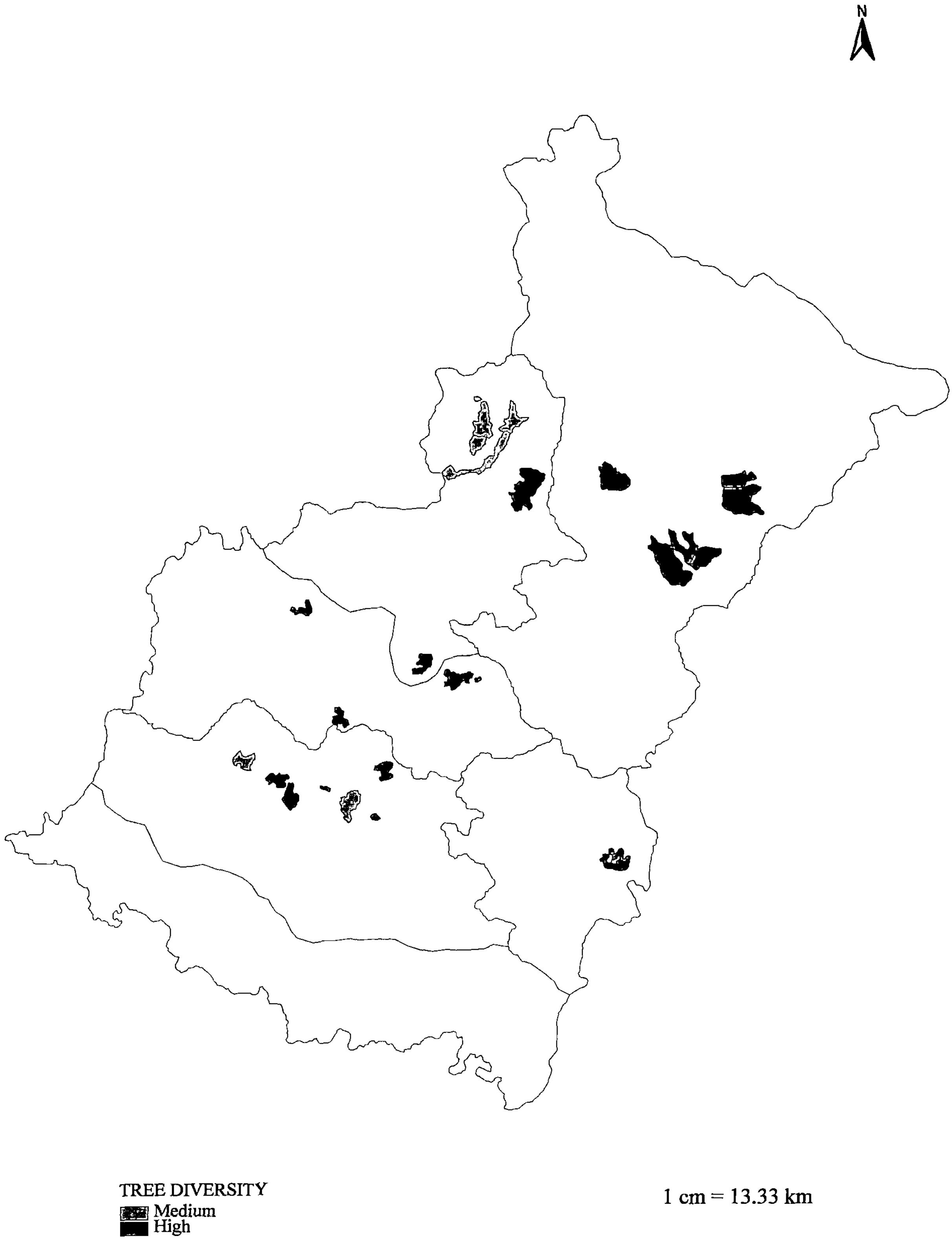


Fig. 3.4 Extent of tree diversity in oak forest patches in Kumaon Himalaya.

Fig. 3.5 Extent of shrub diversity in oak forest patches in Kumaon Himalaya.

3.2.2 Analyses

Densities for trees, shrubs and ground vegetation (herbs and grasses) were calculated following Greig-Smith (1984) for each sampling plot by using following formula,

Density = Number of individuals x 10,000/ Area

Tree and shrub density values were converted into hectare unit while herbs and grasses were calculated in m^2 unit. Standard error and 95% confidence interval were also calculated. The diversity for each layer (tree, shrub and ground vegetation) were calculated by using Shannon-Wiener's diversity index following Magurran (1988),

$H' = - \Sigma \, pi \log pi$

Where pi = proportion of the i^{th} species in the sample

The species richness was calculated by using Margelef's species richness index (Magurran, 1988),

$R = S - 1/ \ln N$

where S = Number of species, N = number of individuals.

For habitat description, mean ± S.D. of density values of main tree species of overall Kumaon Himalaya was also calculated. Kruskal–Wallis one-way ANOVA was used to detect significant statistical differences in density, diversity and richness of all vegetation layers (tree, shrub and ground vegetation) for all oak patches of Kumaon. Further Scheff's test (Zar, 1984) was performed to find out which pair of oak patches was different. All vegetation attributes such as tree density, diversity, richness; shrub density, diversity, richness, ground layer density, diversity, richness along with altitude, number of stumps, lopped trees and cattle dung were subjected to Principal Component Analysis (PCA), to ordinate 23 sites in space.

Apart from PCA, the vegetation of Kumaon was classified on the basis of all tree species and dominant ground vegetation (shrub and herb species) sampled by using TWINSPAN (Two-way indicator species analysis) computer program (Hill, 1979b). The data matrix was constructed in Sites x Species matrix by having sites in column and species in row. This analysis is the most widely used technique for polythetic divisive classification to produce two-way table of sample and species. The same data matrix was again used for ordination of tree species as well as sites by using computer program DECORANA for Detrended Correspondence Analysis (DCA) (Hill, 1979a and Hill & Gauch, 1980). DECORANA was not performed for ground vegetation, as only classification was needed for it.

Stepwise multiple regression was used to obtain regression equations for quantitative correlations between the DCA axis and dominant environmental and vegetation attributes. By incorporating the environmental factors and site parameters of sites into these multiple regression equations, quantitative environmental interpretation of sites or species is possible. A pattern or model for the community types and species distributions could be objectively established by plotting sites or species in the DCA ordination. All data matrices were standardized following Zar (1984) to achieve the normality and reduce heteroscadesticity.

In order to see the most fragmented patches at landscape level, we used Perimeter/ area ratio index and the shape index following the formula, Shape index = Perimeter / 2 x $\sqrt{\pi}$ x Area

Increase in these indices will indicate the most fragmented surveyed oak patches of Kumaon.

Rarity index

A rarity index was generated to find out rare tree species of Kumaon. For the purpose two parameters were taken into account-

a) Qualitative proportion of each tree species in Kumaon (P_{QA})

$$(P_{QA}) = \frac{\text{No. of patches the concerned tree species was encountered}}{\text{Total number of patches (23)}}$$

b) Quantitative proportion of each tree species in Kumaon (P_{QI})

$$(P_{QI}) = \frac{\text{No of individuals of each tree species}}{\text{No of individuals of all the tree species where the concerned species was encountered}}$$

Rarity index for each tree species = $P_{QA} + P_{QI}$

3.3 RESULTS

A total of 63 tree species, 56 shrub species, 90 herb species and 21 grass species were sampled in 23 oak patches of Kumaon Himalaya (Appendix).

3.3.1 Habitat classification

3.3.1.1 *Tree species classification*

Nineteen broad habitat types have been recognised in Kumaon. All the sites having 63 tree species were subjected to TWINSPAN analysis. A total of five homogenous groups in relation to the environmental variables were identified (Fig. 3.6 & 3.7). The left arm of the first dichotomy contained 25 species, which was further divided into two groups. First negative group consisted four species (*Acer cappadocicum, Aesculus indica, Swida* sp. and *Betula alnoides*) characteristic of Binsar Wildlife Sanctuary. Second positive group again consisted two homogenous groups. First group contained *Quercus semecarpifolia* as dominant species and *Toona cerrata, Symplocos chinensis* as co-dominant. This vegetation type is distributed at Daphiadhura, Gasi and Dhakuri. Second group consisted *Abies pindrow* and *Taxus baccata* as dominant species while *Tsuga demosa, Betula utilis* and *Rhododendron barbatum* occurred as co dominant species. This habitat type was found in Pindari, Sobala, Duku, Wachham, Sunderdunga and Munsiary and it represented Mixed Coniferous habitat. Further subdivisions were meaningless and did not provide any ecological information.

The right arm of the first dichotomy had 38 tree species, which further subdivided into two groups. First negative group contained 21 species which had *Quercus leucotricophora, Quercus lanuginosa, Euonymus tingens, Quercus glauca* and *Pinus roxburghii* as dominant species and some other major tree species were *Pinus wallichiana, Pyrus pashia, Cedrus deodara, Cupressus torulosa, Myrica esculenta* and *Swida oblonga* (Table 3.2). These tree species were mainly encountered at Vinaiyak,

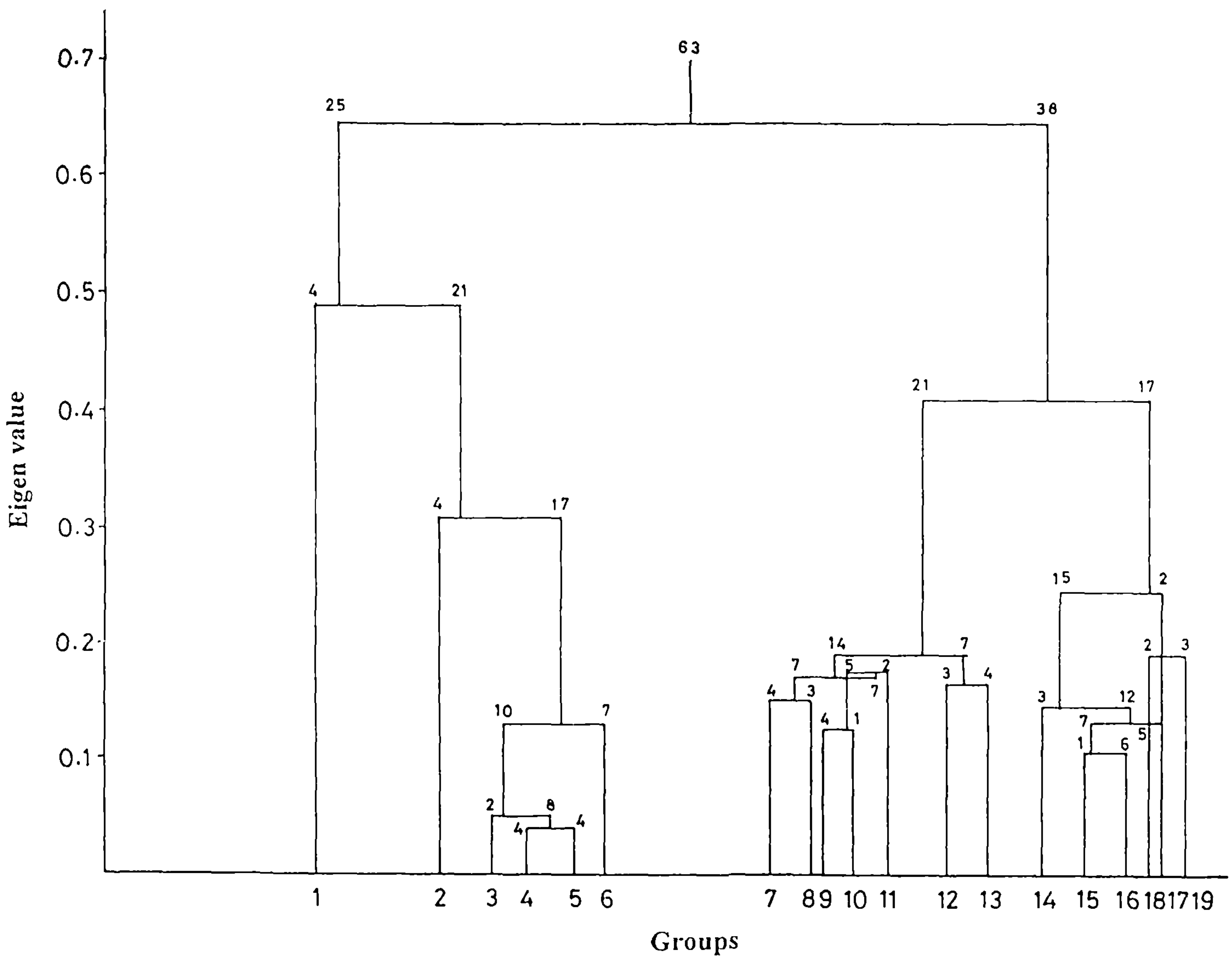


Fig 3.6 TWINSPAN classification of 63 tree species into 19 groups based on the tree species data.

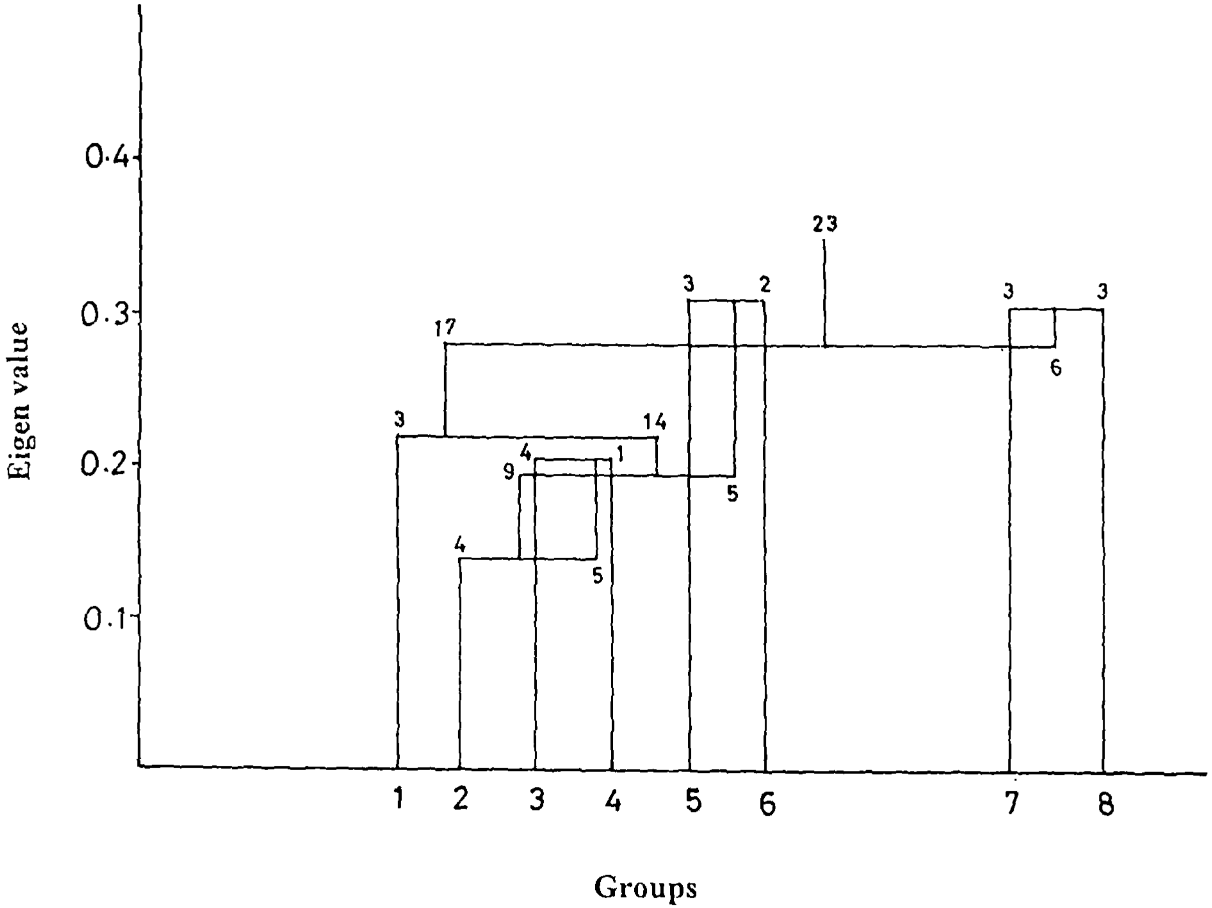


Fig 3.7 TWINSPAN classification of 23 sites into 8 groups based on the tree species data.

Table 3.2 The vegetation communities and their characteristic tree species in Kumaon based on TWINSPAN classification. Comm. = Community

Comm.	Group No.	Sites	Tree species
1	1	Binsar WLS	*Acer caesium, Aesculus indica,* Swida sp., *Betula alnoides*
2	2	Daphiadura Gasi, Dhakuri	*Quercus semecarpifolia, Toona serrata, Dodecademia grandiflora, Symplocos* sp.
3	3,4,5,6	Pindari, Sobala, Duku Wachham, Sunderdunga Munsiary	*Abies pindrow, Jugulans regia, Prunus cerasoides Betula utilis, Rhododendron barbatum,Taxus baccata, Tsuga demosa, Pyrus vestita,Zanthoxylum armatum, Ficus palmata, Morus serrata, Symplocos chinensis, Prunus cornuta, Debregeasia hypoleuca, Acer cappadocicum, Fraxinus* sp., *Dendroephthoe falcata*
4	7,8,9,10,11 12,13	Vinaiyak, Maheshkhan Gager, Jilling, Majtham Gandhura, Mechh	*Cedrus deodara, Cupressus torulosa, Cassia fistula, Quercus lanuginosa, Engelhardia spicata, Ficus auriculata, Daphnephyllum, himalense, Quercus glauca,Pinus roxburghii, Myrica esculenta, Maytenus rufa, Benthamidia capitata, Phoenix humilis, Castanopsis, tribuloides,Quercus leucotricophora, Pyrus pashia, Pinus wallichiana, Euonymus tingens,Swida oblonga, Macaranga pustulata, Picea smithiana*
5	14,15,16,17, 18,19	Mukteshwer, Kilbery Pandavkholi, Sitlakhet Jageshwer, Kunjakharak	*Litsea umbrosa, Populus ciliata, Persea duthiei, Rhododendron arboreum, Alnus nepalensis Viburnum mullaha, Ilex dipyrena, Stranvissia naussea,, Meliosma dillenaeafolia, Rhamnus triqueter, Quercus floribunda,Praxinus micrantha, Symplocos theifolia, Lindera pulcherrima, Lyonia ovalifolia, Euonymus pendulus, Viburnum coriacieum*

Maheshkhan, Gager, Jilling, Majtham, Gandhura and Mechh. At Vinaiyak, *Quercus leucotricophora*, *Pinus wallichiana* and *Cedrus deodara* were the dominant tree species while at Mechh it was *Quercus lanuginosa.* At Mukteshwer, Pandavkholi, Sitlakhet, Jageshwer, Kilbery and Kunjakharak, the dominant tree species were *Lyonia ovalifolia*, *Symplocos theifolia*, *Quercus floribunda*, *Rhododendron arboreum* and *Persea duthiei* where as *Lindera pulcherrima*, *Viburnum mullaha*, *Alnus nepalensis*, *Ilex dipyrena* and *Litsea umbrosa* were the co-dominant tree species (Fig. 3.8 and Table 3.2).

3.3.1.2 ***Ordination of tree species***

The matrix consisting of 23 sites and 63 tree species was subjected to Detrended Correspondence Analysis to ordinate sites as well as species while PCA was performed to ordinate only sites on the basis of some vegetation and environmental attributes. DCA produced an excellent ordination for the Kumaon data, successfully handling the extreme diversity of plant communities from low altitude to high altitude. All the sites and plant species showed meaningful distribution on axis 1 and axis 2 of DCA (Fig. 3.9). The first axis (eigen value = 0.389) is an elevation (low to high) gradient. It represented an ecological series from low altitude, middle altitude and high altitude communities.

Pindari, Sobala, Duku, Wachham, Sunderdunga and Munsiary occupied extreme end of first axis and represented TWINSPAN group 3 (*Abies pindrow*, *Taxus baccata, Betula utilis, Tsuga demosa* etc.), to low altitude sites Mechh, Majtham, Maheshkhan, Sitlakhet that represented TWINSPAN group 4 & 5 (*Pinus roxburghii, Quercus leucotricophora, Pyrus pashia, Quercus floribunda*).

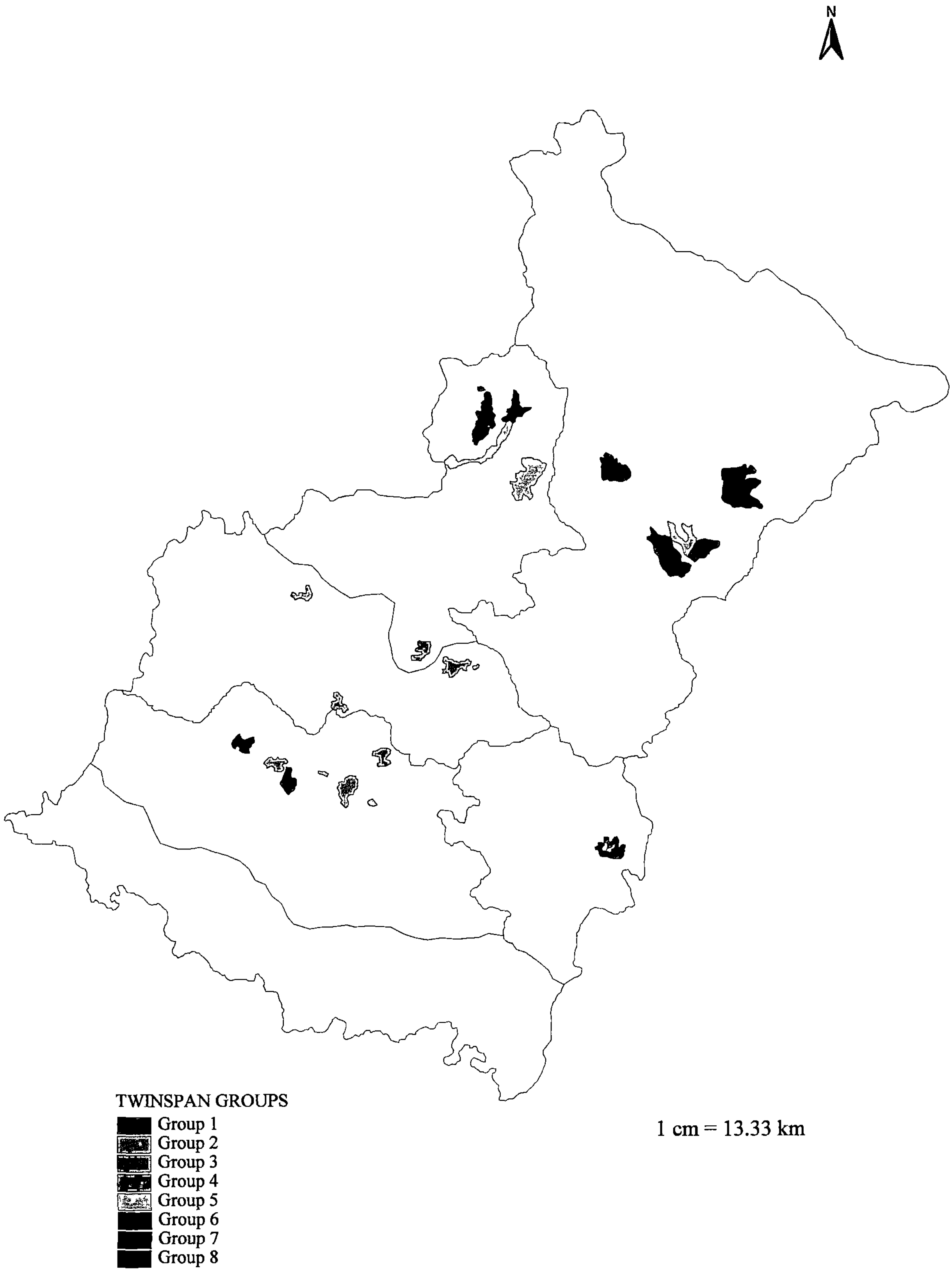


Fig. 3.8 Map showing distribution of the eight TWINSPAN- groups, based on tree species in Kumaon Himalaya.

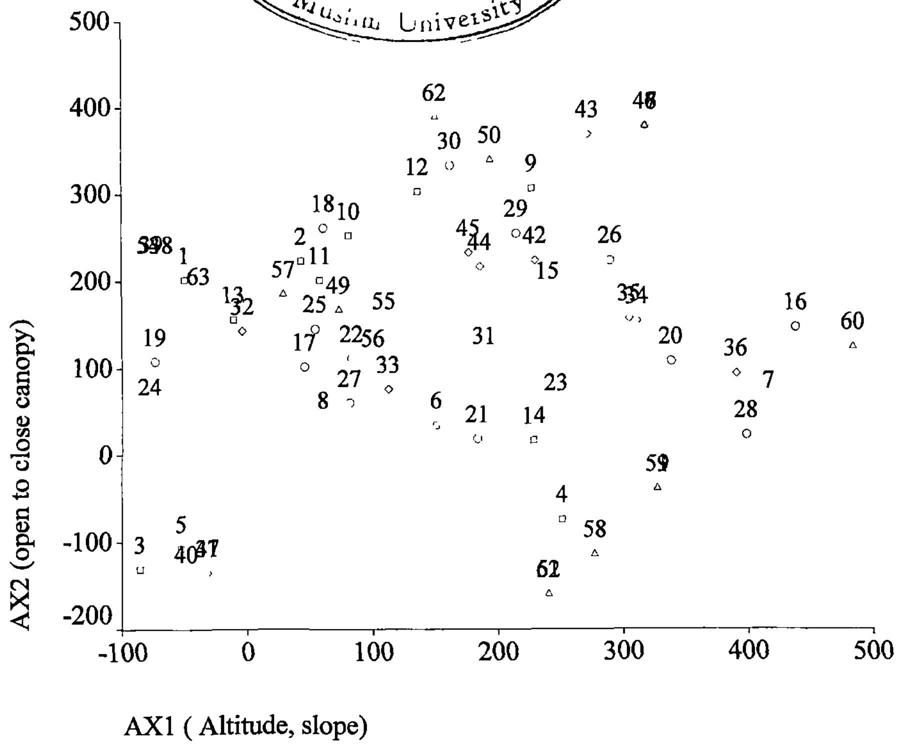


Fig. 3.9 Ordination of different tree species on two axes extracted by DECORANA

Table 3.3 List of tree species with codes used in DECORANA.

SPECIES	CODE	SPECIES	CODE	SPECIES	CODE
Quercus leucotricophora	1	*Viburnum mullaha*	22	*Dendroephthoe falcata*	43
Quercus floribunda	2	*Aesculus indica*	23	*Betula alnoides*	44
Quercus glauca	3	*Myrica esculenta*	24	*Picea smithiana*	45
Quercus semecarpifolia	4	*Cupressus torulosa*	25	*Ficus palmata*	46
Quercus lanuginosa	5	*Ilex dipyrena*	26	*Morus serrata*	47
Rhododendron arboreum	6	*Swida oblonga*	27	*Fraxinus* sp.	48
Rhododendron barbatum	7	*Betula utilis*	28	*Populas ciliata*	49
Lyonia ovalifolia	8	*Meliosma dillenaeafolia*	29	*Symplocos* sp.	50
Persea duthiei	9	*Litsea umbrosa*	30	*Symplocos chinensis*	51
Euonymus tingens	10	*Lindera pulcherrima*	31	*Pyrus vestita*	52
Euonymus pendulus	11	*Praxinus micrantha*	32	*Acer cappadocicum*	53
Symplocos theifolia	12	*Macaranga pustulata*	33	*Maytenus rufa*	54
Pyrus pashia	13	*Jugulans regia*	34	*Viburnum coriacieum*	55
Toona serrata	14	*Tsuga demosa*	35	*Rhamnus triqueter*	56
Abies pindrow	15	*Engelhardia spicata*	36	*Stranvissia naussea*	57
Taxus baccata	16	*Dodecademia grandiflora*	37	*Zanthoxylum armatum*	58
Cedrus deodara	17	*Daphnephyllum himalense*	38	*Debregeasia hypoleuca*	59
Pinus wallichiana	18	*Benthamidia capitata*	39	*Prunus cornuta*	60
Pinus roxburghii	19	*Castanopsis tribuloides*	40	*Phoenix humilis*	61
Acer caesium	20	*Ficus auriculata*	41	*Cassia fistula*	62
Alnus nepalensis	21	*Swida* sp.	42	*Prunus cerasoides*	63

The second axis (eigen value = 0.254) appeared to reflect the canopy cover from open to close. The species associated with open canopy were (*Quercus glauca, Quercus lanuginosa, Cassia fistula, Zanthoxylum armatum, Quercus semecarpifolia*) and sites were Majtham, Gandhura, Mechh, Dhakuri and Wachham while close canopy areas were Gasi, Sobala, Duku and Pandavkholi and species associated were *Quercus semecarpifolia, Toona cerrata, Symplocos theifolia* (Fig. 3.10). These interpretations are largely confirmed by the results of Principal Component Analysis. The first factor (PC 1) explained 44.26% variance and emerged as an open to close canopy forest with tree density and diversity in increasing order while second factor (PC 2) explained 18.26% of variance and showed the characters of increase in shrub density and diversity. The distribution of species and sites was same on the two axis of PCA as on DCA axis (Fig. 3.11, Table 3.3).

Multiple regression of DCA sites ordination scores with environmental and vegetation attributes provided objective, quantitative environmental interpretation for vegetation types. According to regression analysis, DCA axis 1 was significantly positively correlated with altitude (53.5% variance) and further slope also contributed cumulative 62.1% variance in the model (Table 3.4). Axis 2 again appeared to reflect shrub characters and canopy cover gradient. It was positively correlated with these two gradients (Table 3.5), which again clearly interpret the DCA axes for sites and species.

3.3.1.3 *Ground vegetation classification*

Total 17 broad communities of 52 shrub and herb species have been recognized. A total of five major identical homogenous groups, were identified (Fig. 3.12). The left

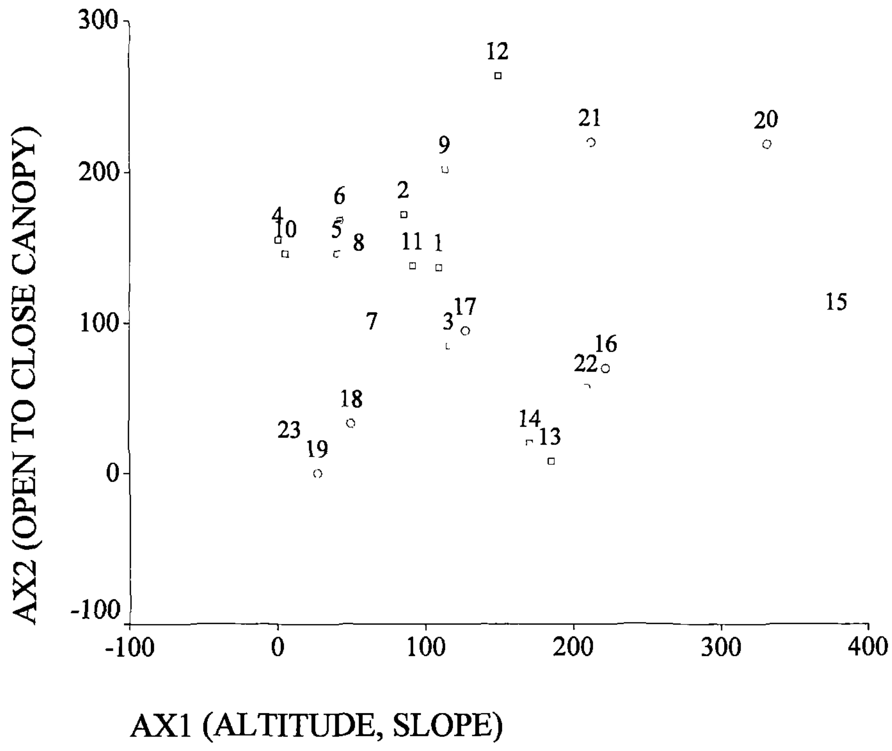


Fig. 3.10 Ordination of sites on the two axes extracted by DECORANA.

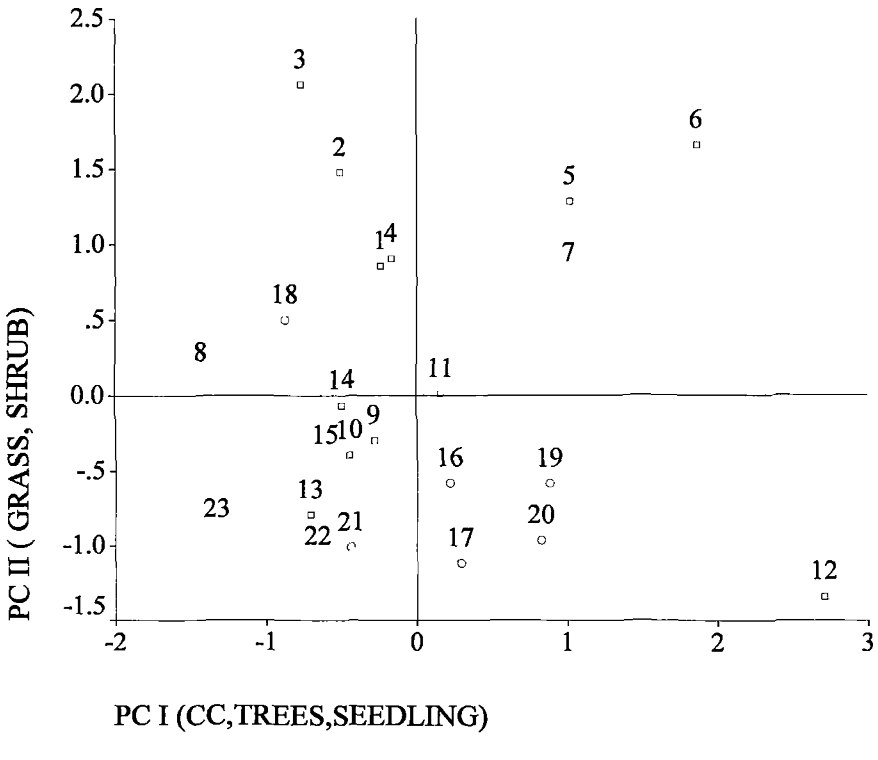


Fig. 3.11 Ordination of sites on two extracted factors from Principal Component Analysis.

Table 3.4 Multiple regression analysis of Axis 1 of DCA with vegetation attributes.

Model	Variables	Correlation	R^2	F	Significance
1	Altitude	+	0.535	24.16	0.001
2	Altitude, Slope	+	0.655	19.05	0.001

Table 3.5 Multiple regression analysis of Axis 2 of DCA with vegetation attributes.

Model	Variables	Correlation	R^2	F	Significance
1	Shrub diversity	+	0.32	10.08	0.05
2	Shrub diversity, Grass richness	+	0.544	11.93	0.001
3	Shrub diversity, Grass richness, Canopy cover	+	0.635	11.01	0.001
4	Shrub diversity, Grass richness, Canopy cover, Shrub density	+	0.714	11.2	0.001

arm of the first dichotomy contained 37 species, which further divided it into 19 and 18 species. The three major communities formed in the left armed dichotomy were *Mahonia* sp., *Valeriana wallichii*, *Desmodium gangeticum* etc. This community represented the sites Pandavkholi, Jageshwer and Gasi. The second community consisted *Pteris biaurita*, *Pyracantha crenulata*, *Myrcine africana*, *Rubus peniculatus*, *Cotoneaster acuminata* etc. It was found in all the oak patches of Askot Wildlife Sanctuary i.e. Duku, Daphiadhura, Majtham, Sobala & Gandhura and Dhakuri (Fig. 3.13). The third and the last community of this dichotomy was dominant among all. The major species were *Wikstroemia canescens*, *Nerium* sp., *Daphne papyracea*, *Athyrium* sp., *Rubus biflorus*, *Berberis aristata*, *Boeninghausienia albiflora*, *Polystichum* sp. etc. and were present in Kilbery, Vinaiyak, Kunjakharak, Maheshkhan, Gager, Jilling, Mukteshwer, Sitlakhet and Munsiyari (Fig. 3.14 and Table 3.6).

The right arm of dichotomy comprised 15 species, which was further divided into one and 14 species (Fig. 3.12). Five homogenous groups were combined to form two communities. The first community contained *Urtica dioca*, *Cratagus* sp., *Argimone maxicana*, *Arisaema flavum* and *Geranium wallichianum*; the community was encountered at Binsar and Mechh. Another community had 10 species such as *Euphorbia prolifera*, *Cercium verutum*, *Berginia legulata*, *Leptodermis kumaonensis*, *Deutzia staminea*, *Trachelospermum lucidum*, *Aechmanthera gossypina* etc. This community was found at higher altitude sites such as Waccham, Sunderdunga and Pindari (Fig. 3.13).

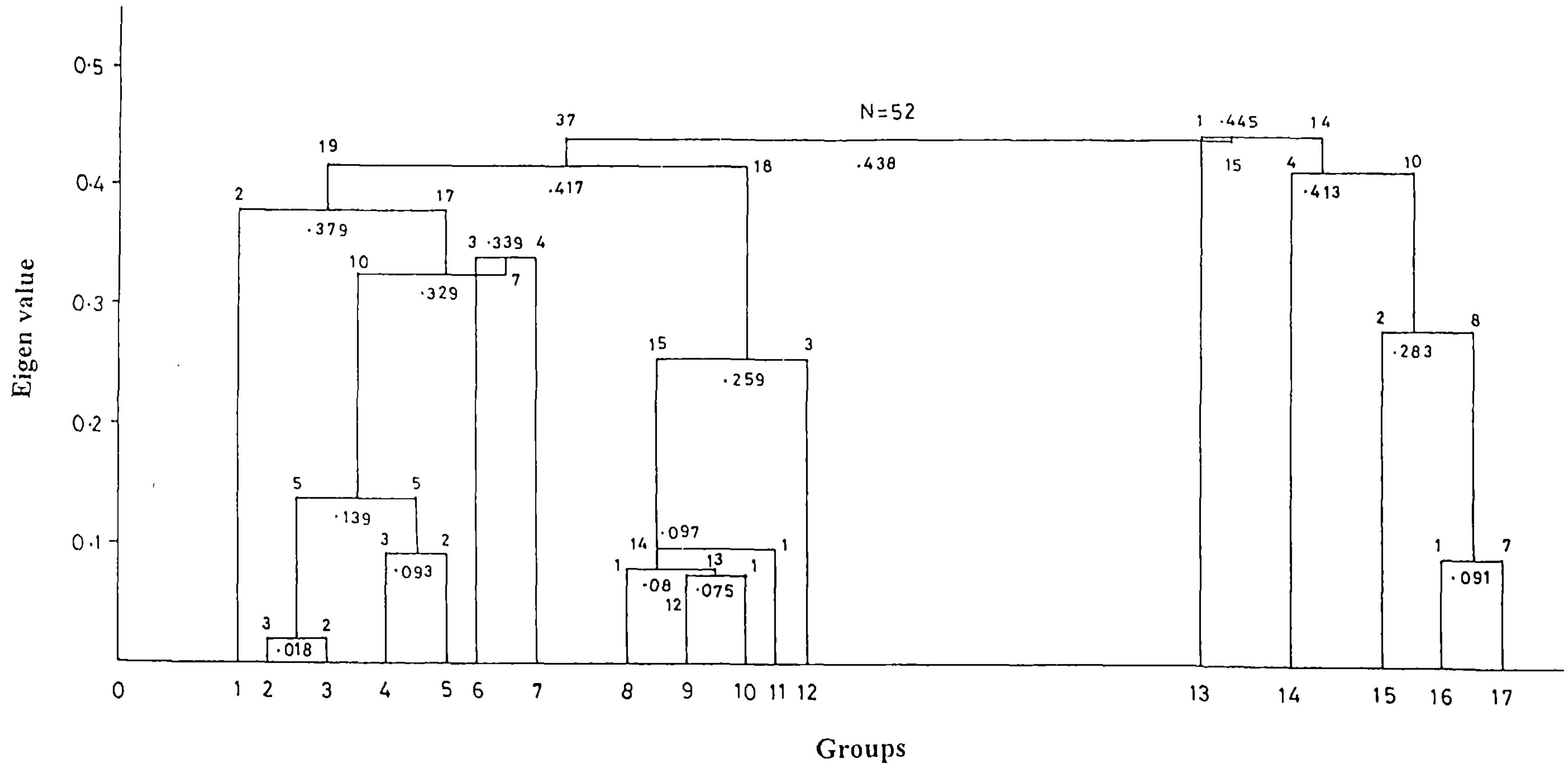


Fig 3.12 TWINSPAN classification of 52 ground species into 17 groups based on the ground vegetation data.

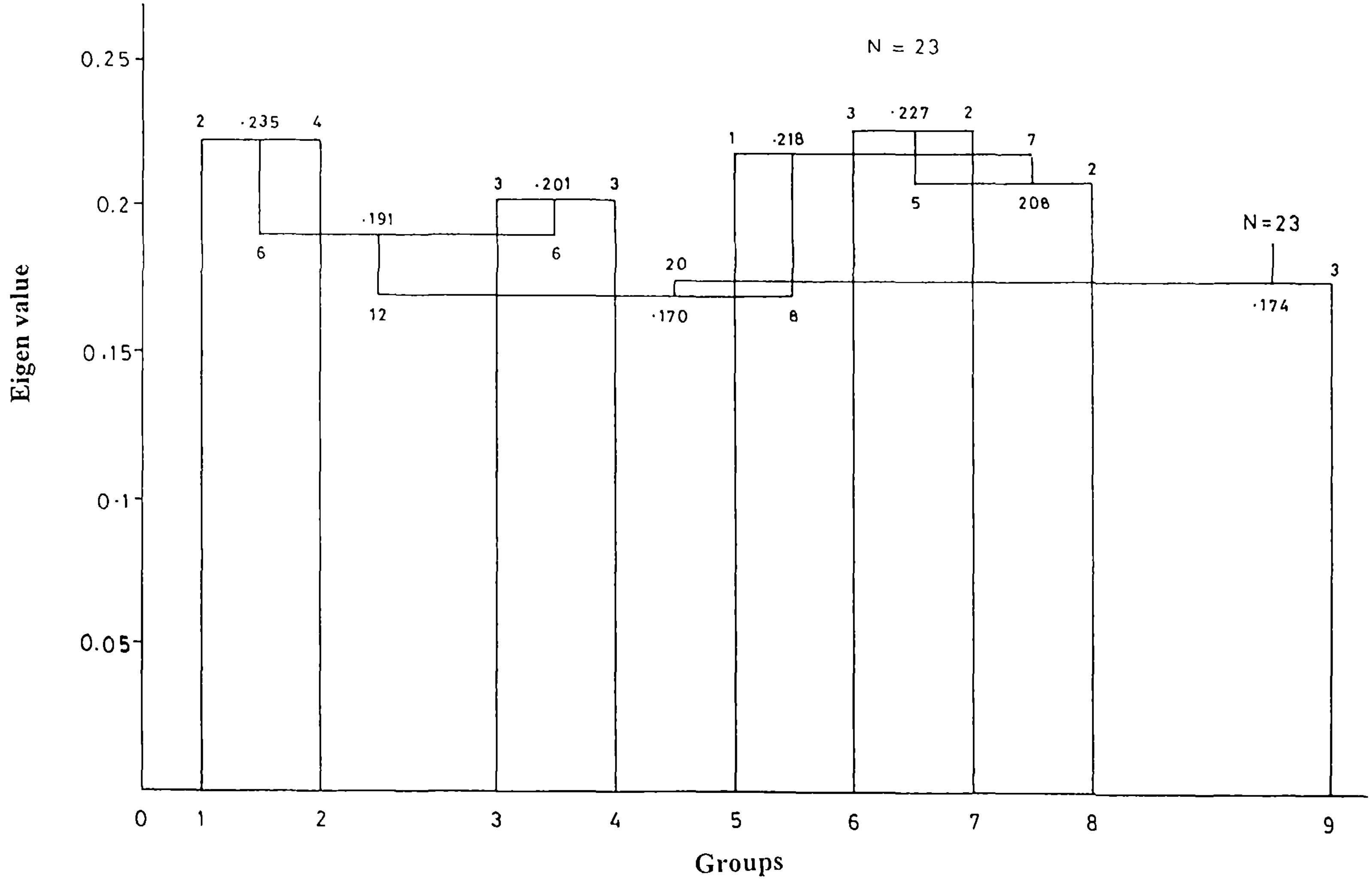


Fig 3.13 TWINSPAN classification of 23 sites into 9 groups based on the ground vegetation data.

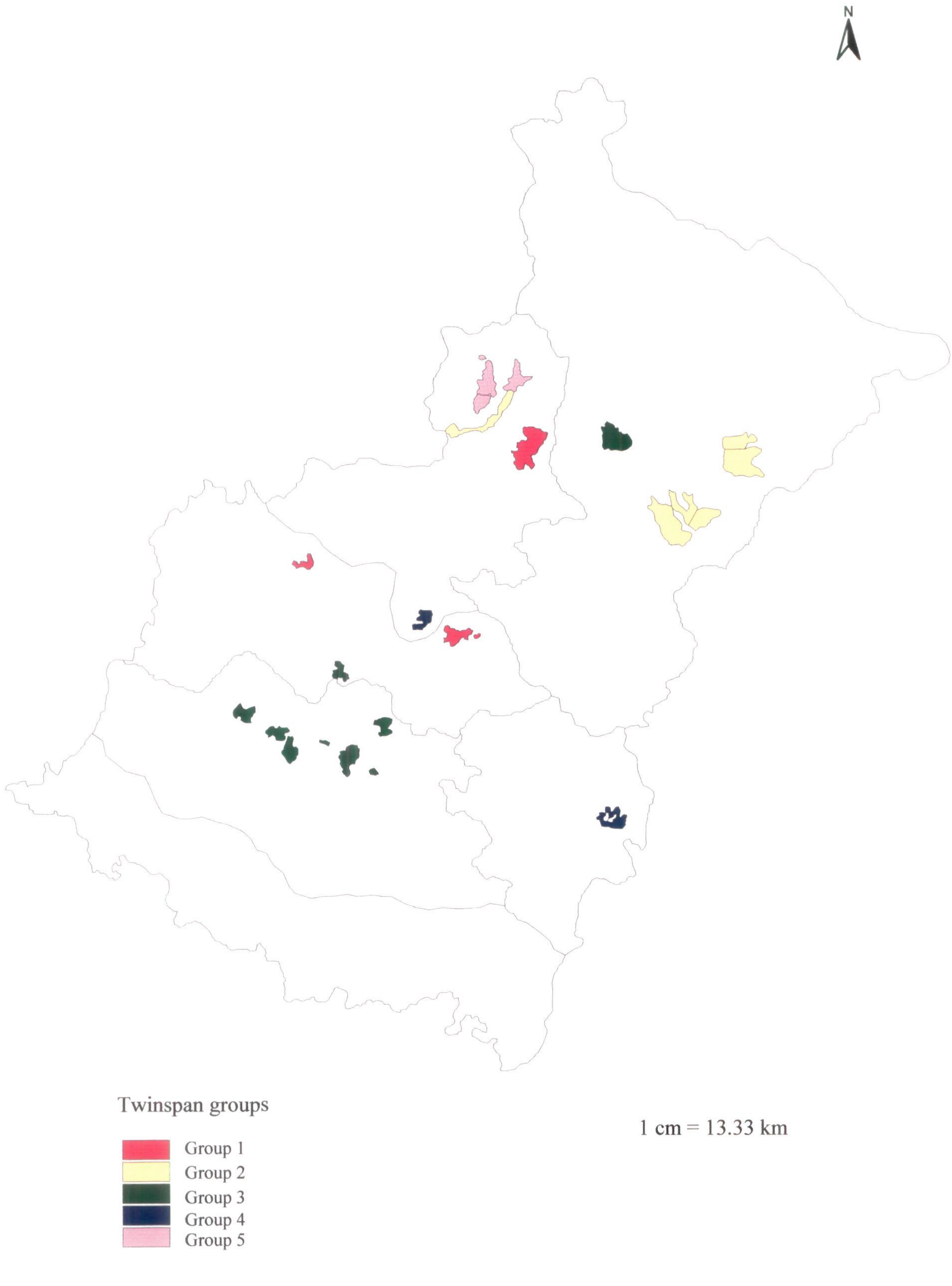


Fig. 3.14 Map showing distribution of five Twinspan- groups based on ground vegetation composition in Kumaon Himalaya.

Table 3.6 The vegetation communities and their characteristic ground species in Kumaon based on TWINSPAN classification.

Comm.	Group No.	Sites	Shrub species
1	1,2,3	Pandavkholi, Jageshwer, Gasi	*Mahonia* sp., *Desmodium elegans, Gaultheria numulanoides, Valeriana wallichii, Origanum ulgare, Boehmenia rugulosa, Polygonum recumbens*
2	4,5,6,7	Dhaphiadhura, Majtham Gandhura, Sobala, Duku Dhakuri	*Cotoneaster acuminata, Asparagus racemosus, Adiantum venustum, Pyracantha crenulata, Pteris biaurita, Myrcine africana, Rubus peniculata, Desmodium gangeticum*
3	8,9,10,11,12	Kilbery, Vinaiyak, Gager Kunjakharak, Jilling, Maheshkhan, Sitlakhet Mukteshwer, Munsiyari	*Wikstroemia canescens, Nerium* sp., *Daphnae papyracea, Athyrium sp, Rubus biflorous, Berberis aristata, Boeninghausienia albiflora, Polystichum* sp, *Thalictrium foliolosum, Pteridium* sp., *Indigofera heterantha, Randia tetrasperma, Arundinella nepalensis, Hypericum oblongifolium, Rubus ellipticus, Rhamnus virgatus, Bistorta amplexicaulis, Hedychium spicatum*
4	13,14	Binsar, Mechh	*Cratagus* sp., *Urtica dioca, Arisaema flavum, Geranium wallichianum, Argimone maxicana*
5	15,16,17	Wachham, Sunderdunga Pindari	*Euphorbia prolifera, Skimmia laureola, Thamnocalamus spathiflorus, Berginia legulata, Leptodermis kumaonensis, Circium wallichii, Deutzia staminea, Aechmanthera gossypina, Trachelospermum lucidum, Polysticum squarossum*

3.3.2 Species composition

The tree, shrub, herb and grass densities varied significantly in different sites (Tables 3.7 & 3.8). The tree density was significantly high at Gasi (995.2 / ha ± 269.4), Gager (915.6 / ha ± 331.6) and Sitlakhet (815.1 / ha ± 257.3) compared to rest of the oak patches. Shrub density was also significantly different in all oak patches and it was highest for Mukteshwer (28158.2 / ha ± 10478.7), Gager (24504.6 / ha ± 11280.7) and Kunjakharak (21470.3 / ha ± 10435.9) while lowest for Mechh (6852.01 / ha ± 4068.38) and Munsiary (7353.31 / ha ± 5059.38).

Significant differences were not observed in different communities for tree density. However, tree density was maximum for *Quercus floribunda-Rhododendron arboreum* community (714.51 / ha ± 70.0) and minimum for *Abies pindrow-Betula utilis* community (492.92 / ha ± 37.53). Shrub density was also not significantly different in all communities but it was maximum for community *Quercus floribunda–Rhododendron arboreum* (16834.9 / ha ± 2863.22) and minimum for *Quercus semecarpifolia–Toona cerrata* (6914.96 / ha ± 431.01) community (Tables 3.9 & 3.10).

The tree layer was dominated by *Rhododendron arboreum* (3861.41 /ha) in whole of Kumaon followed by *Quercus leucotricophora* (2637.06 / ha), *Quercus floribunda* (2538.07 / ha), *Lyonia ovalifolia* (2621 / ha), *Persea duthiei* (1985.39 / ha) (Table 3.11). In Vinaiyak, *Cedrus deodara* (184.71 / ha) was dominant tree species while in Pindari *Rhododendron arboreum* (263.03 / ha) and *Debregeasia hypoleuca* (414.01 / ha) were dominant species. *Quercus floribunda* (266.72 / ha) dominated the tree layer in Binsar Wildlife Sanctuary.

Table 3.7 Mean values of density ± S.E. and confidence limit 95% (C.I.) of quantified trees and shrubs of surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	Trees/ha	± S.E.	%C.I.	Shrub/ha	± S.E.	%C.I.
Kilbery	793.8	311.9	96.66	14092.0	6881	2132
Vinaiyak	590.8	311.9	96.65	20444.0	9351	2898
Kunjakharak	367.8	185.8	.54.32	1470	10436	3049
Maheshkhan	611.3	857.4	265.7	13880	7534	2335
Gager	915.6	331.6	102.8	24505	11281	3496
Mukteshwer	765.1	275	77.01	28158	10479	2934
Jilling	774.7	305.9	134.1	19502	10034	4398
Binsar WLS	743.6	415.9	94.12	14402	10490	2374
Pandavkholi	796.2	212.7	65.92	8855	5395	1672
Sitlakhet	815.1	257.3	130.2	11836	7195	3642
Jageshwer	749	247.9	95.27	16597	8542	3284
Gasi	995.2	269.4	83.54	7776	5058	1568
Dhakuri	313.7	189.1	50.44	6449	5181	1381
Wachham	530.3	385.2	106.77	10386	7795	2160
Sunderdunga	499.3	220.4	77.0	11637	9621	3142
Pindari	326.6	107.6	33.35	12632	10843	3360
Daphiadhura	804.1	246.7	76.44	6519	4326	1340
Majtham	447.5	214.4	66.45	11421	5631	1745
Gandhura	841.6	275.4	76.33	5458	4185	1160
Sobala	582	242.4	75.13	10952	7443	2306
Duku	558.1	243.1	68.76	8616	6583	1862
Munsiary	461.2	231.2	90.64	7353	5059	1983
Mechh	486	245.8	152.35	6852	4068	2521

Table 3.8 Mean values of density ± S.E. and confidence limit 95% (C.I.) of quantified herbs and grasses of surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	Herbs/m²	± S.E.	%C.I.	Grass/m²	± S.E.	%C.I.
Kilbery	18.65	11.1	3.44	37.13	17.14	5.3
Vinaiyak	17.83	12.81	3.97	39.93	17.52	5.4
Kunjakharak	23.85	13.9	4.1	48.79	45.6	13.3
Maheshkhan	10.4	8.5	2.63	27.83	16.82	5.2
Gager	14.23	9.93	3.08	35.4	15.7	4.8
Mukteshwer	15.2	11.05	3.1	44.73	20.08	4.6
Jilling	12.71	7.95	3.49	34.11	17.02	7.46
Binsar WLS	15.88	14.08	3.19	17.68	15.69	3.5
Pandavkholi	12.4	14.07	4.36	18.78	19.5	6.0
Sitlakhet	14.57	13.51	6.84	11.03	9.27	4.69
Jageshwer	16.42	14.94	5.74	17.4	15.8	5.8
Gasi	35.48	20.77	6.44	2.2	4.4	1.4
Dhakuri	33.98	17.35	4.63	17.45	13.87	3.7
Wachham	17.93	16.72	4.63	25.78	18.36	5.1
Sunderdunga	21.16	24.61	8.04	9.31	18.7	6.1
Pindari	31.8	19.13	5.93	4.20	6.13	1.9
Daphiadhura	19.53	16.34	5.06	16.13	17.89	5.5
Majtham	20.2	14.84	4.6	33.9	18.07	5.6
Gandhura	17.6	10.71	2.97	27.08	13.31	3.7
Sobala	22.83	14.42	4.47	7.3	9.1	2.8
Duku	22.3	14.37	4.1	8.95	8.93	2.5
Munsiary	22.87	14.54	5.7	9.5	8.19	3.2
Mechh	24.74	14.17	8.7	13.03	20.41	12.6

Table 3.9 Tree species density (TDEN), Shrub species density (SDEN) and Standard error (SE) and confidence limit (95%) in different communities based on TWINSPAN classification.

Community	TDEN	± S.E.	%C.I.	SDEN	± S.E.	%C.I.
1. *Aesculus indica*	743.6	415.9	94.12	14402	10490	2374
2. *Quercus semecarpifolia*	704.3	202.9	397.8	6915	431.01	844.7
3. *Abies pindrow*	492.9	37.5	73.5	10263	799.3	1566.6
4. *Quercus leucotricophora*	666.77	67.92	133.13	14580	2719	5329.2
5. *Quercus floribunda*	714.5	70.0	137.2	16835	2863.2	5611.8

Table 3.10 Tree species diversity (TDIV), tree species richness (TRIC), shrub diversity (SDIV) and shrub richness (SRIC) in different communities based on TWINSPAN classification.

Community	TDIV	TRIC	SDIV	SRIC
1. *Aesculus indica*	1.31	1.39	1.07	1.06
2. *Quercus semecarpifolia*	1.23	1.33	0.87	0.82
3. *Abies pindrow*	1.03	1.03	0.83	0.74
4. *Quercus leucotricophora*	1.27	1.34	1.13	1.11
5. *Quercus floribunda*	1.26	1.31	1.26	1.20

Table 3.11 Mean values of density ± S.E. and confidence limit 95% (C.I.) of major tree species of surveyed oak patches of Kumaon Himalaya during 1996-97.

Tree species	Density	± S.E.	CI (95%)
Abies pindrow	150.85	97.38	95.43
Acer caesium	76.14	35.12	18.39
Aesculus indica	47.33	19.28	10.12
Alnus nepalensis	55.94	26.59	11.37
Betula utilis	84.93	36.77	41.61
Cedrus deodara	110.54	76.74	50.13
Cupressus torulosa	112.15	37.01	32.43
Euonymus tingens	70.03	37.77	21.36
Ilex dipyrena	70.16	37.17	17.17
Juglans regia	70.52	21.82	16.16
Lindera pulcherrima	117.91	65.53	42.81
Litsea umbrosa	92.22	52.56	32.57
Lyonia ovalifolia	113.95	55.45	22.66
Myrica esculenta	86.56	33.27	18.82
Persia duthiei	110.3	92.83	42.88
Pinus roxburghii	81.54	43.97	25.98
Pinus wallichiana	92.35	60.0	52.59
Pyrus pashia	49.73	17.83	9.34
Quercus floribunda	181.29	102.26	53.56
Quercus glauca	59.14	47.28	53.50
Quercus lanuginosa	167.42	70.56	52.27
Quercus leucotricophora	138.79	93.39	41.99
Quercus semecarpifolia	108.36	45.59	29.78
Rhododendron arboreum	175.52	74.64	31.18
Swida oblonga	68.34	27.91	14.61

Swida sp.	109.56	91.38	56.63
Symplocos theifolia	129.77	107.11	66.38
Taxus baccata	150.85	97.38	95.43
Toona serrata	51.94	24.22	17.94
Tsuga demosa	93.95	24.77	34.33
Viburnum mullaha	82.34	41.12	20.14

The shrub layer also plays a major role in vegetation analysis. *Myrcine africana* (91299.86 / ha) was the dominant shrub species all over the Kumaon followed by *Athyrium* sp. (64645.31 / ha) and *Nerium* sp. (62405.28 / ha) (Table 3.12). *Myrcine africana* was found to be maximum at Kunjakharak (13269.64 / ha) and Gager (12356.3 / ha) while *Rubus ellipticus* was dominant at Pindari (2830.85 / ha) and Binsar (2753.93 / ha). The other species of Rubus i.e. *Rubus biflorus* was maximum in number at Pandavkholi (3096.24 / ha), Sunderdunga (3037.27 / ha) and Pindari (2756.36 / ha). *Berberis aristata* was dominant at Jageshwer (1725.05 / ha), Kunjakharak (1430.81 / ha) and Wachham (1326.96 / ha). *Daphne papyracea* was found to be maximum at Dhakuri and Sunderdunga (4600.14 / ha), Kilbery (3132.67 / ha) and Vinaiyak (3063.07 / ha).

3.3.3 Species diversity and richness

Species diversity and richness also varied significantly between the sites (Tables 3.13 & 3.14). However, tree species diversity was found maximum at Daphiadhura (1.53) in Askot Wildlife Sanctuary followed by Gasi (1.45), Gager (1.44) and Mukteshwer (1.43). Tree species richness was maximum at Daphiadhura (1.76) and Gasi (1.44).

Shrub diversity and richness was also statistically different between the sites. It was highest in Vinaiyak (1.61 & 1.54 respectively) followed by Kilbery (1.49) and Mukteshwer (1.38). Shrub richness was also high at Mukteshwer (1.48).

3.3.4 Species of special conservation concern

Using the individuals of tree species sampled in whole Kumaon the generated rarity index value ranged from 0.03 to 0.40. The tree species falling between 0.03 to 0.20

Table 3.12 Mean values of density ± S.E. and confidence limit 95% (C.I.) of major shrub species of surveyed oak patches of Kumaon Himalaya during 1996-97

Shrub species	Density	± S.E.	CI (95%)
Argimone maxicana	2064.1	1918.3	2658.6
Urtica dioca	5017.2	7525.2	5574.69
Arundinella nepalensis	2953.9	1399.96	665.5
Athyrium sp.	3055.3	1594.7	666.3
Berberis aristata	984.6	318.7	130.2
Euphorbia prolifera	1862.1	1231.9	853.6
Cratagus sp.	1492.2	281.4	246.7
Daphne papyracea	1808.7	1190.2	486.43
Desmodium gangeticum	2020.7	1252.4	613.6
Indigofera heterantha	1667.4	959.1	455.9
Mahonia sp.	554.1	205.5	164.4
Myrcine africana	6521.4	4760.3	2493.56
Nerium sp.	3670.9	2656.2	1262.65
Polystichum sp.	1526.6	630.93	257.8
Pteridium sp.	2189.9	1687.5	721.7
Pteris cretica	3046.9	1391.5	609.88
Pyracantha crenulata	812.9	356.7	233.1
Rubus biflorus	1618.2	758.9	316.9
Rubus ellipticus	1955.0	1361.5	687.0

Table 3.13 Tree species diversity (TDIV), tree species richness (TRIC), Shrub species diversity (SDIV) and Shrub species richness (SRIC) quantified at surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	TDIV	TRIC	SDIV	SRIC
Kilbery	1.42	1.66	1.4	1.4
Vinaiyak	1.12	1.2	1.6	1.5
Kunjakharak	0.77	0.78	1.1	0.9
Maheshkhan	1.00	1.13	1.2	1.2
Gager	1.45	1.59	1.3	1.4
Mukteshwer	1.43	1.66	1.3	1.5
Jilling	1.4	1.64	1.2	1.2
Binsar WLS	1.32	1.39	1.1	1.1
Pandavkholi	1.33	1.18	1.3	1.2
Sitlakhet	1.34	1.22	1.2	1.1
Jageshwer	1.36	1.41	1.1	1.3
Gasi	1.45	1.44	1.1	1.1
Dhakuri	0.72	0.71	0.6	0.6
Wachham	0.99	0.95	0.8	0.7
Sunderdunga	0.84	0.79	0.5	0.5
Pindari	0.67	0.62	0.8	0.7
Daphiadhura	1.53	1.77	0.8	0.7
Majtham	1.17	1.27	1.2	1.1
Gandhura	1.31	1.21	0.6	0.5
Sobala	1.25	1.40	0.9	0.7
Duku	1.24	1.41	0.7	0.6
Munsiary	1.18	1.25	0.7	0.6
Mechh	1.26	1.35	0.7	0.7

Table 3.14 Herb species diversity (HDIV), herb species richness (HRIC), grass species diversity (GDIV) and grass species richness (GRIC) quantified at surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	HDIV	HRIC	GDIV	GRIC
Kilbery	0.75	0.67	0.93	0.74
Vinaiyak	0.78	0.76	0.40	0.38
Kunjakharak	0.91	0.89	2.64	0.73
Maheshkhan	0.71	0.7	1.12	0.88
Gager	0.81	0.82	1.13	0.89
Mukteshwer	0.76	0.76	1.16	0.88
Jilling	0.66	0.63	1.07	0.83
Binsar WLS	0.83	0.84	0.67	0.70
Pandavkholi	0.81	0.85	0.31	0.29
Sitlakhet	0.83	0.82	0.49	0.44
Jageshwer	0.99	1.03	0.71	0.63
Gasi	0.92	0.93	0.07	0.08
Dhakuri	0.79	0.56	0.27	0.25
Wachham	0.40	0.38	0.69	0.61
Sunderdunga	0.93	0.91	0.28	0.34
Pindari	1.02	0.88	0.24	0.24
Daphiadhura	0.76	0.74	0.26	0.34
Majtham	0.79	0.75	0.94	0.72
Gandhura	0.71	0.66	0.82	0.64
Sobala	0.61	0.55	0.38	0.41
Duku	0.72	0.62	0.27	0.26
Munsiary	0.84	0.75	0.31	0.28
Mechh	0.82	0.72	0.36	0.32

range values were considered rare. *Betula utilis* (0.03), *Tsuga demosa* (0.06), *Quercus glauca* (0.06), *Pinus wallichiana* (0.09), *Taxus baccata* (0.12), *Cupressus torulosa* (0.15), *Picea smithiana* Wall. (0.16), *Abies pindrow* (0.16) and *Cedrus deodara* (0.17) were found to be rare tree species in Kumaon. Except *Quercus glauca* all the above-mentioned rare tree species were found in Pindari region only while *Pinus wallichiana, Cupressus torulosa, Picea smithiana* and *Betula utilis* were found in Vinaiyak reserve forest also.

On the basis of Perimeter / Area ratio and shape index, it was concluded that Gager, Jilling and Pandavkholi were the most fragmented patches and Gandhura, Dhakuri and Duku were the least fragmented patches. Increase in fragmentation denotes increase of abrupt habitat change, an ecologically undesirable influence on most species populations and communities.

3.4 DISCUSSION

The main advantage of numerical methods in evaluating representativeness is that they summarized information about the range in variation in species composition found in whole Kumaon region in an effective and meaningful way. Numerical methods make no claim to being objective as the very choice of method is a subjective decision (Birks, 1987). However, statistical significance is not enough to qualify a site for selection but biological significance is also needed as a basis for sound selection for prioritizing area.

TWINSPAN found to be a satisfactory method, to classify different communities of whole Kumaon. This polythetic divisive classification divides sites into groups on the basis of all the species information. This division was not made on the basis of presence/absence of one species, but on the basis of species composition for the entire site. It was not possible to consider all 902 sampling plots individually due to limitation of the software program. So all the sampling plots of each site were pooled and one site was considered as one quadrate / sample. Since my main emphasis was to classify sites it was taken on Y-axis. None of the species was found to be > 5% cover at each site. This could be a sampling error also. As suggested by Margules (1986), representativeness should be used as the first stage in selecting nature reserves. By classifying sites into groups with different species compositions, one can ensure that all these major groups are represented in the selection.

Detrended Correspondence Analysis (DCA) was applied in order to attempt to solve the two problems i.e. the 'arch effect' and compression of points at the end of first axis. The first axis was divided into a number of segments and within each segment, the second axis scores are recalculated so that they have an average of zero. Though the DCA axis were clearly defined but unfortunately, the data lacked direct observation on soil moisture, which could be an important factor for the distribution of species (Rikhari *et al.* 1989).

Various studies have been conducted on vegetation of Kumaon by several workers (Saxena & Singh, 1980; Saxena & Singh, 1982; Tiwari, 1982; Tiwari & Singh, 1984; Singh *et al.* 1984; Singh & Singh, 1984; Saxena *et al.* 1985; Upreti *et al.* 1985; Singh & Singh, 1987a; Singh *et al.* 1987; Tiwari & Singh, 1985; Rikhari *et al.* 1989; Adhikari *et al.* 1992 and Dhar *et al.* 1997). The main aim of this study was to identify and classify the vegetation communities and also in relation with pheasant abundance.

Tree species density was significantly different at all sites. It was found to be high at Gasi and Gager. Another study by Rikhari *et al.* (1989) showed that tree density was higher at Gager than what he estimated. But the diversity index value for all the sites was higher than the value reported by Saxena & Singh (1982), Tiwari (1982), Singh & Singh (1984) and Rikhari *et al.* (1989) for oak forests of different localities in Kumaon Himalaya. *Pinus roxburghii* and *Quercus semecarpifolia* are typical west Himalayan elements and are poorly represented in Nepal and further east (Ohsawa *et al.* 1986). Two other oak forests (*Quercus leucotricophora* and *Quercus floribunda*) are widely distributed in the west with higher concentration in Central Himalaya (Singh & Singh, 1986). Both the forests were distributed in most of the surveyed sites except at higher elevation. *Abies pindrow*, *Taxus baccata* and *Betula utilis* form the sub-alpine forest throughout the Himalayas (Dhar *et al.* 1997). *Abies pindrow* community dominated in some of the patches of Askot Wildlife Sanctuary, Pindari, Wachham, Sunderdunga and Munsiary. Tree density, diversity and shrub density, diversity was low in *Abies pindrow-Betula utilis* forest as diversity and richness decreases at higher elevations (Singh *et al.* 1994 and Rawal & Pangtey, 1994). Same results were available from other areas also (Frankel, 1977; Brithers & Spingarn, 1992 and Knops *et al.* 1995). *Quercus semecarpifolia* forest was represented at Daphiadhura (AWS), Gasi and Dhakuri. Tree diversity range (0.72-1.53) was similar as recorded by Dhar *et al.* (1997) at *Quercus semecarpifolia* forest in Askot Wildlife Sanctuary (1.41) but shrub diversity range (0.6-1.1) was lower than what has been reported for Askot Wildlife Sanctuary (1.36). It showed a diversity decline in shrubs.

Forest composition (tree, shrub and ground vegetation) of whole Kumaon corresponds with the forest reported by others for the region. *Quercus leucotricophora* forest represented the elevation of 1800-2300m (1200-2300m by Singh & Singh, 1986;

1700-2100m by Singh *et al.* 1994) while *Quercus semecarpifolia* forest was present 2200-3000m altitude range (2400-3600m by Singh & Singh, 1986; 2366-3000m by Singh *et al.* 1994). The Shannon-Wiener (H') diversity values were also almost similar as reported by others (Singh *et al.* 1994). These values are even similar to those of temperate communities in adjacent Nepal Himalaya (Ohsawa *et al.* 1975) and elsewhere (Monk, 1967).

As reported by Dhar *et al.* (1997) that > 50% species of this region are non-native species. The area has received plant elements from adjoining regions of tropical Asia (Indo-China and Indo-Malaya, Mani, 1974) and Indo-Gangetic plains (Spate, 1957). Though the data were not collected and analyzed by keeping native species in mind but the distribution of non-native species is known from the Himalayas (Maheshweri, 1962). However, the change in native flora because of non-native species could lead to long-term change in ecosystem processes (Ramkrishnan & Vitousek, 1989).

Human interference causes great impact on forest structure (Tyser & Worley, 1992). In Kumaon, most of the low altitude and middle altitude oak forest patches are densely populated as compared to high altitude forest (see Chapter 8). So the chances of destruction of forest and invasion of non-native species are more in *Quercus leucotricophora* and *Quercus semecarpifolia* forest. Disturbances may interact in complex ways to affect species composition (Collins & Barber, 1985; Steuter *et al.* 1990 and Noy-Meir, 1995). Frequent fire events, heavy grazing, lopping and felling of trees caused great damage to vegetation. The sites where grazing was prohibited or low were found to be having very high ground cover as compared to other sites such as Jilling and Kunjakharak.

Some species such as *Alnus nepalensis* is fast growing. Ohsawa (1991) considered it as a 'habitat pioneer' species as it can occupy the newly formed habitat. Similarly, the expanding *Pinus roxburghii* poses serious threat to native oak (*Quercus leucotricophora* and *Quercus floribunda*) in whole Kumaon as it was reported earlier also (Singh & Singh, 1987b). The acidic nature of *Pinus roxburghii* does not allow any broad-leaved species to survive (Singh *et al.* 1984). All oak species are facing severe threats because they are lopped and felled for fodder and fuel purposes. This leads to reduction in seed production (Saxena & Singh, 1984). Destruction at large scale, of selected species may change plant communities. Other valuable tree species such as *Abies pindrow*, *Taxus baccata, Tsuga demosa* and *Cedrus deodara* are felled because of their timber value. This community is mainly represented in Pindari but *Abies pindrow* and *Cedrus deodara* were in good population in Vinaiyak reserve forest also. So the protection of this community is necessary.

I tried to map the actual quantified data on different oak patches of Kumaon Himalaya. Though, the interpretation of vegetation and habitat analysis through aerial photography of Kumaon has already been done (Tiwari & Singh, 1984; 1987). But the true assessment of land use pattern and habitat types through remote sensing and GIS, is lacking. These two tools could be used effectively in mapping, monitoring and management of natural resources. Landscape parameters are very effective in evaluating the fragmentation of patches and if they are evaluated by taking data of early years, then the habitat loss can be assessed in successive years. To identify, potential areas for conservation in Kumaon, it is often necessary to complement remote sensing techniques with vegetation analyses.

CHAPTER 4

STATUS AND ABUNDANCE OF PHEASANT SPECIES

4.1 INTRODUCTION

There are 16 genera and 51 species (69 taxa) of pheasants (Delacour, 1977) known worldwide. With the exception of Congo Peafowl *Afropavo congensis*, which is the exception to Zaire in Central Africa, (Crowe *et al.* 1986), rest of the pheasant species are endemic to Asia. In Asia, pheasants are distributed from Indonesia at 8° E through to northeastern China at 50° N and from 45° E in the Caucus to 145° E in Japan. Within the Indian limits, the distribution of pheasant species is throughout the country. Of the 51 species of pheasants, 17 are known to occur within the Indian limits (Ali & Ripley, 1987). Out of 17 species, eight species (47.05%) are endemic to eastern Himalaya, one species to western Himalaya, two species to western and central Himalaya, one species to central and eastern Himalaya, four species throughout the Himalayas and one species is found in other parts of India (Table 4.1).

Pheasants belong to a highly specialized group of avian inhabitants of a fragile habitat where least human exploitative pressure sets off irreversible chain reaction and their status in any habitat can be considered an index of the well being of that ecosystem (Jayal, 1982). Also, the size of the distribution range of a species and abundance (density) of its population are important indices to assess its conservation situation (Wu Zhikang *et al.* 1994). Keeping this in view, many workers and conservationists (Gaston *et al.* 1981, Gaston, 1983b, Sharma & Pandey. 1989, Kaul & Ahmad, 1993, Sathyakumar, 1993 and

Table 4.1 Distribution of different pheasant species endemic to different parts of the India with special reference to Himalayas.

Himalayan region	Species
Eastern Himalayas	Blood pheasant, Blyth's Tragopan, Temminck's Tragopan, Eared pheasant, Hume's pheasant, Peacock pheasant, Sclater's Monal, Green Peafowl
Central & Eastern Himalayas	Satyr Tragopan
Western Himalayas	Western Tragopan
Western & Central Himalayas	Koklass, Cheer
Throughout the Himalayas	Red Junglefowl, Kalij, Blue Peafowl, Himalayan Monal
Rest of India	Grey Junglefowl

Pandey, 1993) have conducted preliminary surveys and long term studies (Ghosh, 1997 and Khaling, 1998) on status and distribution of pheasant species in different parts of the Himalayas and elsewhere. This chapter deals with the distribution and abundance of different pheasant species found in Kumaon Himalaya with following objectives,

- To map the current distribution of different pheasant species at various locations of Kumaon Himalaya.
- Abundance (encounter rates) of different pheasant species at various sites in Kumaon.
- Abundance predictors for Kalij and Koklass in terms of habitat variables and threat factors.
- Similarity in sites on the basis of presence/absence of different pheasant species.
- Spatial analysis on Kalij and Koklass abundance with habitat attributes such as tree cover, shrub diversity and herb diversity.

4.2 METHODOLOGY

4.2.1 Data collection

A review of the available literature on status distribution and population studies of Himalayan pheasants was done. Also, various sites of Kumaon Himalaya, which hold various habitat types with great altitudinal variation, were selected in a hope to encounter all the representative pheasant species of Kumaon Himalaya. The sites to be covered were selected from the toposheets published from Survey of India, a Govt. of India publication to get easy access to the sites during surveys. Help for the selection of sites for the surveys was also considered from previous studies (Kaul, personal comments, Young *et al.* 1987 and Ahmed, 1994) carried out in this region and elsewhere in the

Himalayas (Gaston, 1981, Pandey, 1993 and Sathyakumar, 1993) regarding habitat types and site characteristics.

I conducted extensive surveys over periods of time with an aim to establish the presence / absence and distribution of various pheasant species in different parts of Kumaon Himalaya. I monitored the presence of different pheasant species in two different ways, extensive monitoring and call counts, in a hope to get evidences of maximum number of species from the study area. Apart from collecting such information from different methods I also selected areas that served sites for intensive ecological studies for various pheasant species.

4.2.1.1 *Extensive monitoring*

Three consecutive surveys were conducted during premonsoon (March-June) & postmonsoon (September-December) 1996 and premonsoon season 1997 to document the distribution and abundance of different pheasant species found in the Kumaon Himalaya. 23 sites of varying sizes having various habitat types were surveyed. All these sites are distributed throughout the Kumaon and were selected in such a way that they represented a sample for the entire region. Sites were surveyed in two seasons (premonsoon & postmonsoon) of the year to document all the representative species found in the Kumaon Himalaya. Each site was surveyed on an average for 3-4 days in each season / survey.

True line transect (Burnham *et al.* 1980) could not be laid at any site in Kumaon. The main assumptions of the line transect method are: a) that all the birds on the transect line are detected, b) birds are detected before they move, c) measurement are accurate, d) there are no double counts of individuals, e) bird detection is independent and f) biases from observers, seasons and weather are well understood (Bibby *et al.* 1992). These assumptions indicate that the process is based on the ability of observer to follow a straight line or segment of straight line (Anderson, 1979). In Kumaon, laying of such straight line at any selected site for abundance estimation and to know presence of different pheasant species was not possible because of the very folded topography and steep and rugged terrain. I therefore used existing network of forest paths/trails passing through different habitat/forest types at varying altitude for searching different pheasant species.

Detection of pheasant species along a trail was rendered very difficult by their shy and elusive nature and sometimes poor detection of birds due to dense understorey vegetation, similar to the experience of Katti (1992) concerning poor detectibility of birds in Arunachal Pradesh forests due to understorey vegetation. Moreover, accurate distance measurement was not possible, as the birds when encountered were highly mobile and easily flushed. Flushing sometimes occurred without the bird being visible and perhaps many birds were missed during the monitoring even when they were close by. Thus almost all the assumptions of the line transect method would have been violated in this study had this method been applied for abundance estimate in terms of unit area. I therefore used trail-monitoring data to obtain relative abundance estimate by calculating the relative encounter rates (Kaul & Ahmad, 1993) rather than attempting to obtain actual density estimate for each species. Direct sighting as well as indirect evidences in the form of droppings and feathers verified the presence of a bird in a particular area (Gaston *et al.* 1981, Gaston *et al.* 1983 and Kaul *et al.* 1995). Each sighting of a species was considered as one group and if a group of birds consisted more than one species then the individuals of each species was considered as one group of that species. Likewise, indirect evidences such as feathers or droppings was also considered as one group and if it consisted feathers or droppings of more than one species then feathers or droppings was considered as separate group for different species.

4.2.1.2 *Call counts*

Few species of pheasant (Koklass, Tragopans, Cheer and Monal) are good callers and their numbers can be estimated by counting the number of calling groups in an area (Gaston, 1980 and Young *et al.* 1987). Call counts were conducted at each surveyed site during premonsoon season, which is the breeding season (Ali & Ripley, 1987) of most of the pheasant species. I used dawn chorus count (Duke, 1989) as an indirect evidence for the presence of different pheasant species. Counting calls at dawn offers a special technique (counting the number of calling birds in a given area) which is both practical and minimizes disturbance to the species during the breeding season, which is in any case undesirable. Vantage points were selected at various places such as hilltops and facing valleys, which helped in recording the calling individuals from as wide an area as possible. The vantage points were attended regularly half an hour before sunrise. No repetition was made on the vantage points, which has been used for call count on other days during the same season of the year. This was done to cover as much area as possible to document maximum number of calling individuals as well as species. Directions of the call were detected by using a compass. This method was only used to know the presence of different calling pheasant species. Identification of calling species and their number were recorded.

4.2.1.3 *Habitat Assessment*

Methodologies for habitat attributes have been discussed in detail in vegetation chapter.

4.2.1.4 *Mapping*

Methodologies for map preparation have been discussed in details in chapter 3.

4.2.2 Data analyses

4.2.2.1 *Abundance estimate*

The direct sightings as well indirect evidences (dropping and feathers) of different pheasant species recorded during the surveys were used to obtain estimates of status, abundance and distribution of different pheasant species in Kumaon Himalaya. Each sighting was considered as one group. If the individuals in a sighting belonged to more than one species, then individuals of each species were considered as one group for that species. The indirect evidences like droppings and feathers found during the monitoring were also considered as a group and if the droppings or feathers were composed of several species then those were considered as different groups of each species. The indirect data recorded for different species were not added with direct sightings of pheasant species data for abundance estimates.

The sightings of groups (direct and indirect) of different pheasant species were summarized to calculate encounter rates (groups / 100 man hours of observation) for individual monitoring as well as overall encounter rates for different sites for each species. The summarized data were also used to calculate species diversity and richness for each site using Shannon-Wiener's diversity and Margalef's index (Magurran, 1988),

$$H' = - \Sigma\, pi \times \ln pi$$

where pi is the proportion of the individuals found in the i^{th} species.

The species richness was calculated by using following formula,

$$D_{MG} = \frac{S-1}{\ln N}$$

Where S = Total number of species in a sample and N = Total number of individuals in a sample.

4.2.2.2 *Similarity in Sites*

Single Linkage cluster analysis (nearest neighbour method) was performed on the basis of presence/absence of different pheasant species to see similarity in sites in terms of pheasant species composition (Gauch, 1989). In this analysis Jaccard similarity measure index was used (Norusis, 1990).

4.2.2.3 *Abundance predictors during surveys*

The data obtained out of monitoring for pheasant species and quantification of habitat variables on 790 sampling plots at 23 sites were arranged into species-habitat parameters and site characteristic matrix for performing multiple regression analysis (Table 4.2). The species like Cheer, Monal and Satyr Tragopan were encountered at few sites with low sample size so these species were not included in the analysis. Only Kalij and Koklass were taken into account for the analysis to develop a general statement

Table 4.2 **List of variables used in Multiple regression analysis.**

S No.	Variables code	Variables	Transformation
1.	TSD	Tree species density	Standardised, correlated with ALT, dropped,
2.	TDIV	Tree species diversity	Standardised
3.	TRIC	Tree species richness	Standardised, correlated with TDIV, dropped
4.	SSD	Shrub species density	Standardised
5.	SDIV	Shrub species diversity	Standardised
6.	SRIC	Shrub species richness	Standardised, correlated with SDIV, dropped
7.	HD	Herb Species density	Standardised
8.	HDIV	Herb species diversity	Standardised
9.	HRIC	herb species richness	Standardised
10.	GD	Grass species density	Standardised, correlated with SRIC, dropped
11.	GDIV	Grass species diversity	Standardised, correlated with ALT, dropped
12.	GRIC	Grass species richness	Standardised, correlated with SRIC, dropped
13.	CUT	Number of trees cut	Standardised, correlated with SRIC, dropped
14.	LOP	Number of trees lopped	Standardised, correlated with HDIV, dropped
15.	CD	Number of dung piles	Standardised
16.	PSZ	Oak-patch size	Standardised
17.	HUP	Human population	Standardised
18.	LIP	Livestock population	Standardised
19.	NV	Number of villages	Standardised
20.	ALT	Altitude	Standardised

regarding the effect of various habitat parameters and disturbance factors on the abundance of these species in Kumaon. The habitat parameters from individual sampling plots were used to generate the mean value for each parameter for each site. The matrix was composed of abundance parameters for Kalij and Koklass, and habitat variables and disturbance factors. All the parameters were standardised to bring uniformity and normality in the data set by using given below formula (Zar, 1984),

$$Z = \frac{X - \mu}{\sigma}$$

where X = Value of parameter, μ = Mean value, σ = Standard deviation

Standardization is very useful to check one variable to that of others when two are expressed in different units (Davis, 1973). The standardized variables were subjected to correlation analysis to check for multiple collinearity. Variables showing intercorrelation were excluded from multiple regression analysis.

4.2.2.4 *Spatial analyses*

Abundance of different pheasant species (groups / 100 man-hours of observation) was divided into low (0-20), medium (20.1-40) and high (>40) categories. The habitat attributes (tree cover, shrub diversity, herb diversity and herb richness) were used as base theme layer and abundance of different pheasant species was overlaid. All the habitat attributes values were arranged into the ordinal scale value of low, medium and high. To observe the relationship in abundance and habitat attributes in spatial space, Spearman's rank correlation was performed on map. Distribution of combination of pheasant species

Fig. 4.1 Distribution of different pheasant species in and around proposed Pindari Wildlife Sanctuary in Bageshwer district.

found at various sites in and around proposed Pindari Wildlife Sanctuary was also mapped (Fig. 4.1).

4.3 RESULTS

4.3.1 Distribution pattern of different pheasant species

A total of 23 extant forest patches (sites) of varying sizes at different places in the five districts of Kumaon Himalaya were visited during the survey periods (Table of sites in chapter 2). A total of 682 hours and 30 minute field hours were spent in the field during three consecutive surveys to document status, distribution and abundance of different pheasant species (Table 4.3). Total five pheasant species were documented from the surveyed region. The results obtained from the surveys indicated that the species were not uniformly distributed throughout the region. The maximum number of pheasant species (4) was encountered from Pindari and Wachham reserve forests. The following is the description of each species found during the surveys.

a) Whitecrested Kalij (*Lophura leucomelana*): The highly variable Kalij pheasant extends, in its various races, from the Indus to northern Thailand (Delacour, 1977 and Vaurie, 1965). In the Himalayas it is characteristics of the front ranges rather the interior valleys, occurring mainly between 1200–2500m. The Whitecrested Kalij was found at 14 sites out of 23 sites covered during the surveys of Kumaon Himalaya, thought to be most abundant species in the region. The species was encountered between the altitude range of 1660-2550m. The abundance varied between the sites. Maximum encounter rate (55.55 groups / 100 man hours of observation) was recorded for Jilling followed by

Table 4.3 Time spent (h = hours, m = minutes) in field during the surveys (premonsoon & postmonsoon 1996 and premonsoon 1997) of Kumaon Himalaya.

Sites	Pre 96	Post 96	Pre 97	Total Time
Kilbery	19h 40m	33h	-	52h 40m
Vinaiyak	21h 5m	37h	10h 35m	68h 20m
Kunjakharak	22h 20m	37h	7h 10m	66h 20m
Maheshkhan	-	17h 5m	17h 25m	34h 30m
Gager	-	13h 10m	3h 30m	16h 40m
Mukteshwer	-	22h	11h 30m	33h 30m
Jilling	-	9h	-	9h
Binsar	23h 25m	21h 58m	-	45h 38m
Pandavkholi	-	-	6h 35m	6h 35m
Sitlakhet	-	-	3h	3h
Jageshwer	-	-	5h 10m	5h 10m
Gasi	-	-	17h 55m	17h 55
Dhakuri	-	17h 50m	-	17h 50
Wachham	36h 45m	24h 25m	-	61h 5m
Sunderdunga	-	-	15h 20m	15h 20m
Pindari	-	-	20h 5m	20h 5m
Daphiadhura	-	35h	11h 30m	46h 30
Majtham	-	15h 5m	8h 40m	23h 45m
Gandhura	-	15h 30m	17h 40m	33h 10
Sobala	-	17h 50m	14h 50m	32h 40m
Duku	-	19h 35m	26h	40h 35m
Munsiary	-	-	7h 30m	7h 30m
Mechh	-	-	14h 30	14h 30m
Total time spent				**682h 30m**

Binsar Wildlife Sanctuary (38.2 groups / 100 man hours of observation), Maheshkhan (28.32 groups / 100 man hours of observation), whereas no sightings of Kalij were recorded at the sites Kilbery, Sitlakhet, Jageshwer, Gasi, Munsiary, Dhakuri and Sunderdunga. The details of encounter rates for rest of the sites are provided in Table 4.4.

b) Koklass (*Pucrasia macrolopha*): The Koklass has an extensive range from Afghanistan to eastern China and north to Manchuria, but Himalayan population which extends as far east as central Nepal, are disjunct from those of China, being replaced by a gap of about 1,500 km (Vaurie, 1965).

Earlier records (Wilson, quoted by Hume and Marshal, 1879, Whistler, 1926a) described for this species were to be common but not below 2000m altitude. In Kumaon where the abundance appeared to be more the forest generally supported a well-developed understorey. The direct sightings and indirect evidences (dawn chorus call counts) about the presence indicated this species to be most abundant and widely distributed among all the pheasant species found throughout the Kumaon Himalaya. This species was sighted between the altitudinal range from 1830-3180m. The species was encountered at 15 sites and heard at 16 sites but collectively they were either heard or sighted at 20 sites out of 23 surveyed sites. The highest encounter rate (28 groups / 100 man-hours of observation) was recorded for Pindari reserve forest followed by Binsar (23.9 groups / 100 man-hours of observation). Koklass were neither heard nor encountered at Jilling, Sitlakhet and Gasi.

Table 4.4 Encounter rate (groups / 100 man-hours of observation) of different pheasant species in different sites in the Kumaon Himalaya during surveys of 1996-97. KOH = Koklass heard

Site	Kalij	Koklass	Cheer	Monal	Satyr	KOH
Kilbery	0	4.1	0	0	0	11
Vinaiyak	14.0	1.5	1.5	0	0	8
Kunjakharak	4.3	5.8	0	0	0	7
Maheshkhan	28.3	7.7	0	0	0	5
Gager	6.5	0	0	0	0	6
Mukteshwer	6.0	3.0	0	0	0	4
Jilling	55.6	0	0	0	0	0
Binsar	38.2	23.9	0	0	0	24
Pandavkholi	15.2	0	0	0	0	5
Sitlakhet	0	0	0	0	0	0
Jageshwer	0	14.4	0	0	0	4
Gasi	0	0	0	0	0	0
Dhakuri	0	5.6	0	0	0	7
Wachham	11.7	7.3	5.8	7.3	0	2
Sunderdunga	0	5.5	0	11.5	6.7	0
Pindari	9.3	28.0	0	28.0	18.6	6
Daphiadhura	1.8	5.4	0	0	0	0
Majtham	2.5	0	0	0	0	1
Gandhura	15.0	6.0	0	0	0	4
Sobala	0	4.0	0	0	0	0
Duku	4.7	0	0	0	0	1
Munsiary	0	0	0	33.3	16.6	2
Mechh	0	6.7	0	0	0	0

c) Cheer pheasant (***Catreus wallichii***): The Cheer pheasant formerly ranged from Pakistan to Kali-Gandaki river in Nepal in Western Nepal (Ali & Repley, 1987, Delacour, 1977). In Pakistan the species has disappeared from all areas except Azad Kashmir, although attempts have been made to reintroduce this species in the Margalla hills (Mirza, 1981). The species never occurred in the Valley of Kashmir (Ward, 1906, Osmaston, 1927 and Bates & Lowther, 1952). This species was found to be the most threatened species among all the pheasant species occurring in the Kumaon Himalaya and the species was encountered between 2300-2520m altitude ranges. The species was encountered at Vinaiyak and Wachham only with low abundance of 1.5 and 5.8 groups / 100 man-hours of observation respectively. Indirect evidences like droppings and feathers were found at Pindari and Sobala in Askot Wildlife Sanctuary, which definitely supported their presence, but abundance of this species for these areas could not be generated on this basis.

d) Himalayan Monal (*Lophura impejanus*): The Himalayan Monal occurs practically throughout the Western and Central Himalayas, from Afghanistan in the Safed Koh (Whitehead, 1910), to Bhutan, being replaced by to the east by Sclater's Monal (*L. sclateri*) (Delacour, 1977). Being large and conspicuous bird, found in the open areas (Gaston, 1981), its presence is always reported by casual visitor and is very well known to local people. This species was mainly distributed and encountered in the areas where commercial exploitation of natural resources was marginal and had very low disturbance. The species was seen between the altitude from 2520-3300m. The Monal was encountered at Pindari, Sunderdunga, Wachham, and Munsiary reserve forests. The abundance (encounter rate) recorded for the species was highest at Munsiary (33.33 groups / 100 man-hours of observation) followed by Pindari (28 groups / 100 man-hours of observation), Sunderdunga (11.5 groups / 100 man-hours of observation) and Wachham (7.3 groups / 100 man-hours of observation). The species was not recorded from 19 sites out of 23 surveyed sites from the surveyed region.

e) Satyr Tragopan (*Tragopan satyra*): According to Young & Kaul (1987), though Kumaon marks the boundary between the ranges of Western Tragopan and Satyr Tragopan, there are no physical boundary barriers holding their population apart and thus there is possibility of finding two species close together. From Kumaon eastward upto Bhutan the Satyr Tragopan is the only species of the genus occurring all along the Himalayas. Western Arunachal Pradesh is the eastern Himalayan limit of Satyr Tragopan distribution in India. Recent studies (Zhang Guang-mei & Zhang Zheng wang, 1993 & Ma Shilai *et al.* 1995) extended the farther eastern distribution of the species outside the Indian limits in Dulondjiang (Nujian Nature Reserve) of the Gaolongonshan Region in the Yunnan Province of China. The species was seen at three locations (Pindari, Sunderdunga and Munsiary reserve forests) in Kumaon with few encounters between the altitude range from 2280-3140m. The highest encounter rate (18.6 groups / 100 man-hours of observation) was recorded for Pindari and it was 16.6 groups and 6.7 groups / 100 man-hours of observation for Wachham and Sunerdunga reserve forests respectively.

```
                         Squared Euclidean Distance

                     0         5        10        15        20        25
Sites          Num   +---------+---------+---------+---------+---------+

DHAKURI         13   -+
MECHH           23   -+
JAGESHWER       11   -+-----------------------+
KILBERY          1   -+                       I
SOBALA          20   -------------------------+
WACHHAM         14   -------------------------+
PINDARI         16   -------------------------+
VINAIYAK         2   -------------------------+-----------------------+
GANDHURA        19   -+                       I                       I
DUKU            21   -+                       I                       I
MAJTHAM         18   -+                       I                       I
DAPHIADHURA     17   -+                       I                       I
PANDAVKHOLI      9   -+                       I                       I
BINSAR           8   -+                       I                       I
MUKTESHWER       6   -+                       I                       I
GAGER            5   -+                       I                       I
MAHESHKHAN       4   -+-----------------------+                       I
KUNJAKHARAK      3   -+                       I                       I
SITLAKHET       10   -+-----------------------+                       I
GASI            12   -+                       I                       I
JILLING          7   -------------------------+                       I
SUNDERDUNGA     15   -+-----------------------------------------------+
MUNSIARY        22   -+
```

Fig. 4.2 Dendrogram using Single Linkage on the basis of presence/absence of pheasant species.

4.3.2 Similarity in sites on the basis of presence / absence of different pheasant species

Single linkage cluster analysis combined 23 sites into nine groups (Fig. 4.2). Sunderdunga and Munsiary formed separate group by having Koklass, Monal and Satyr species while only Koklass was found at Kilbery, Jageshwer, Mechh and Dhakuri. The sites Gandhura, Duku, Majtham, Daphiadhura, Pandavkholi, Binsar, Mukteshwer, Gager, Maheshkhan and Kunjakharak formed separate group on the basis of presence of Kalij and Koklass. Maximum species were found in Pindari and Wachham areas of Bageshwer district. Both the sites formed different groups on the basis of Cheer, which was present only at these sites. Cheer was present in Vinaiyak with Kalij and Koklass, while in Sobala it was in combination with Koklass. Gasi and Sitlakhet showed similarity with no sightings of any pheasant species.

4.3.3 Abundance predictors for pheasant species

Stepwise multiple regression analysis was performed on Kalij and Koklass abundance as dependent variable and vegetation & disturbance variables as independent variables. Besides abundance, Koklass heard at various sites were also considered as an independent variable for the analysis to establish relationship between the groups encountered and heard. Regression analysis extracted livestock population in the first model for Koklass. It accounted for 33% of variance and it was positively correlated with the Koklass abundance. Koklass preferred pristine habitat where grazing occurs correlated with Koklass heard also, accounting 63% variance with livestock population, indicating for short duration of the year and human does not inhabit the area. It was also positively that it was encountered at the places where it was heard too (Table 4.5).

The multiple regression included herb richness (HRIC), herb diversity (HDIV) and grass diversity (GDIV). These variables together explained 70.3% of variation in Kalij abundance. While herb diversity was negatively correlated, herb richness and grass diversity was positively correlated with Kalij abundance. The regression of Kalij abundance with these habitat variables was significant (Table 4.6).

4.3.4 Spatial analysis

Spatial analysis was performed between pheasant species abundance and vegetation parameters. Spearman's rank correlation analysis test showed some significant results between pheasant abundance and vegetation attributes.

a) Whitecrested Kalij: Kalij showed positive correlation with tree cover ($r_s = 0.485$, $p < 0.05$) in different patches on map. Some patches like Maheshkhan and Binsar had high tree cover as well as high Kalij abundance (Fig. 4.3). Whereas Sunderdunga, Munsiary, Jageshwer, Sitlakhet and Mechh had medium tree cover but no Kalij was found here. Sunderdunga had low shrub diversity and had low Kalij abundance too. Wachham, Pindari, Dhakuri, Munsiyari, Sobala, Duku, Daphiadhura, Gandhura and Mechh had medium shrub diversity but only Sobala and Daphiadhura had low Kalij abundance. Binsar and Maheshkhan had high shrub diversity as well as high Kalij abundance (Fig. 4.4).

Table 4.5 Multiple regression analysis for Koklass abundance in Kumaon Himalaya. R^2 = coefficient of determination, C = correlation, LIP = Livestock population, KOH = Koklass heard.

Model	R^2	C	F value	Significance
1. LIP	0.33	+	10.34	0.004
2. KOH	0.63	+	17.2	0.000

Table 4.6 Multiple regression analysis for Kalij abundance in Kumaon Himalaya. R^2 = coefficient of determination.

Model	R^2	Correlation	F value	Significance
1. Herb richness	0.431	+	15.87	0.001
2. Herb diversity	0.573	-	13.44	0.00
3. Grass diversity	0.703	+	14.96	0.00

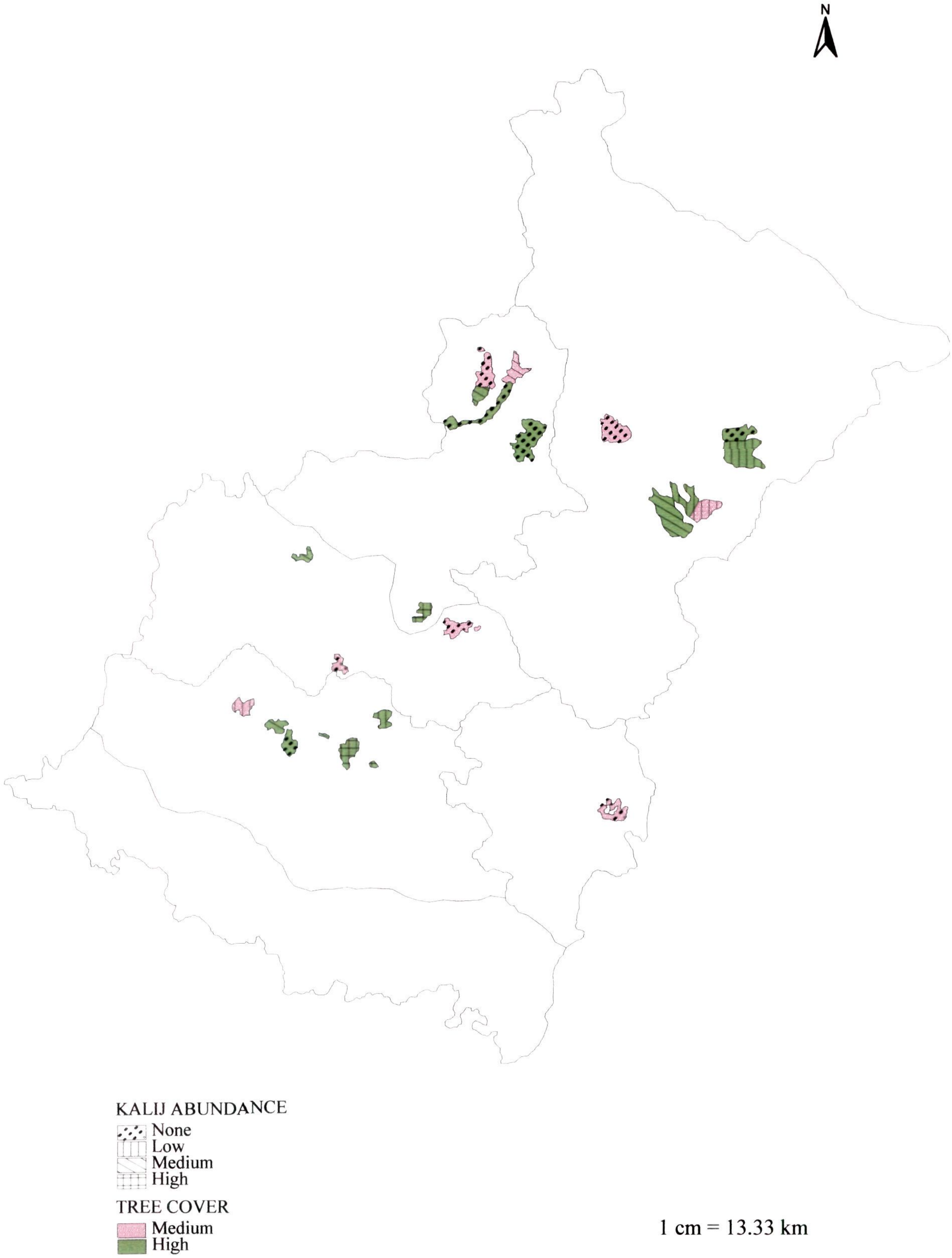


Fig. 4.3 Kalij abundance in relation to tree cover in Kumaon Himalaya.

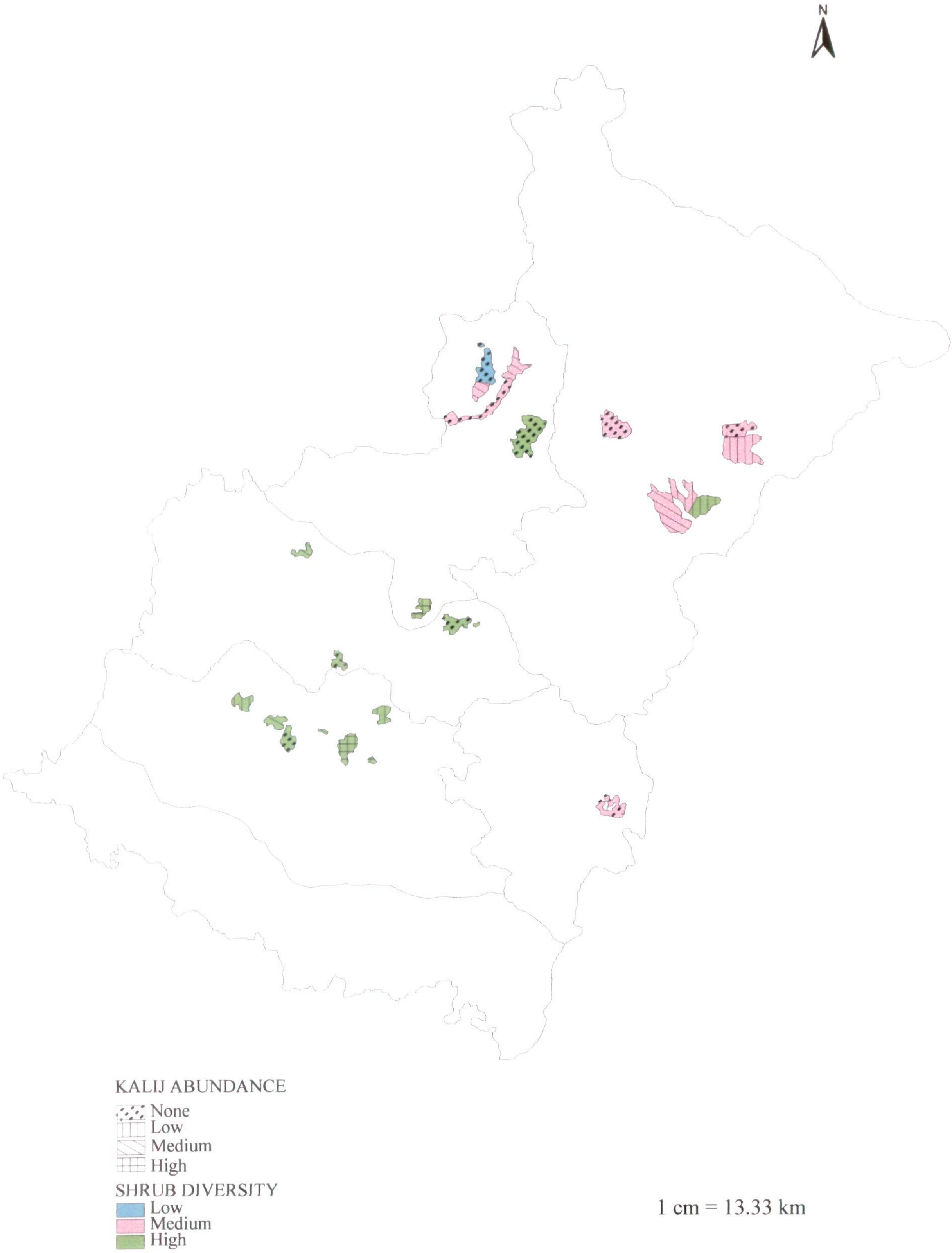


Fig. 4.4 Kalij abundance in relation to shrub diversity in Kumaon Himalaya.

b) Koklass: No significant correlation was found between Koklass abundance and vegetation layers. But Koklass were found maximum in Pindari and Binsar. No Koklass were found at many surveyed forest patches. Binsar had high shrub diversity as well as high Koklass abundance (Fig. 4.5). Vinaiyak, Mukteshwer and Sobala had low Koklass abundance. Only Binsar had high tree cover together with high Koklass abundance while in contrast Pindari had medium tree cover and high Koklass abundance (Fig.4.6).

c) Cheer: No significant relation was found between Cheer abundance and vegetation attributes. Cheer was found only in Wachham and Vinaiyak area. Wachham had medium shrub diversity and high tree cover along with high Cheer abundance. While Vinaiyak had high shrub diversity (Fig. 4.7) and high tree cover (Fig. 4.8) with medium Cheer abundance. But DFA results showed that Cheer preferred high grass cover with low tree cover. These vegetation layers were based on general vegetation sampling for the mentioned areas and here they are referred as available habitat.

d) Himalayan Monal: Significant negative relations were found in Monal abundance with tree cover (r_s = - 0.407, $p < 0.05$) and shrub diversity (r_s = - 0.521, $p < 0.05$) on map. Monal was found only in Sunderdunga, Pindari, Wachham and Munsiary. Pindari and Munsiary had high shrub diversity along with high Monal abundance (Fig. 4.9). Sunderdunga had medium shrub diversity with medium Monal abundance. Wachham had high tree cover together with medium Monal abundance (Fig. 4.10).

e) Satyr Tragopan: It was found only in Sunderdunga, Pindari and Munsiary. Test on map showed that Satyr abundance was negatively correlated with tree cover (r_s = - 0.628,

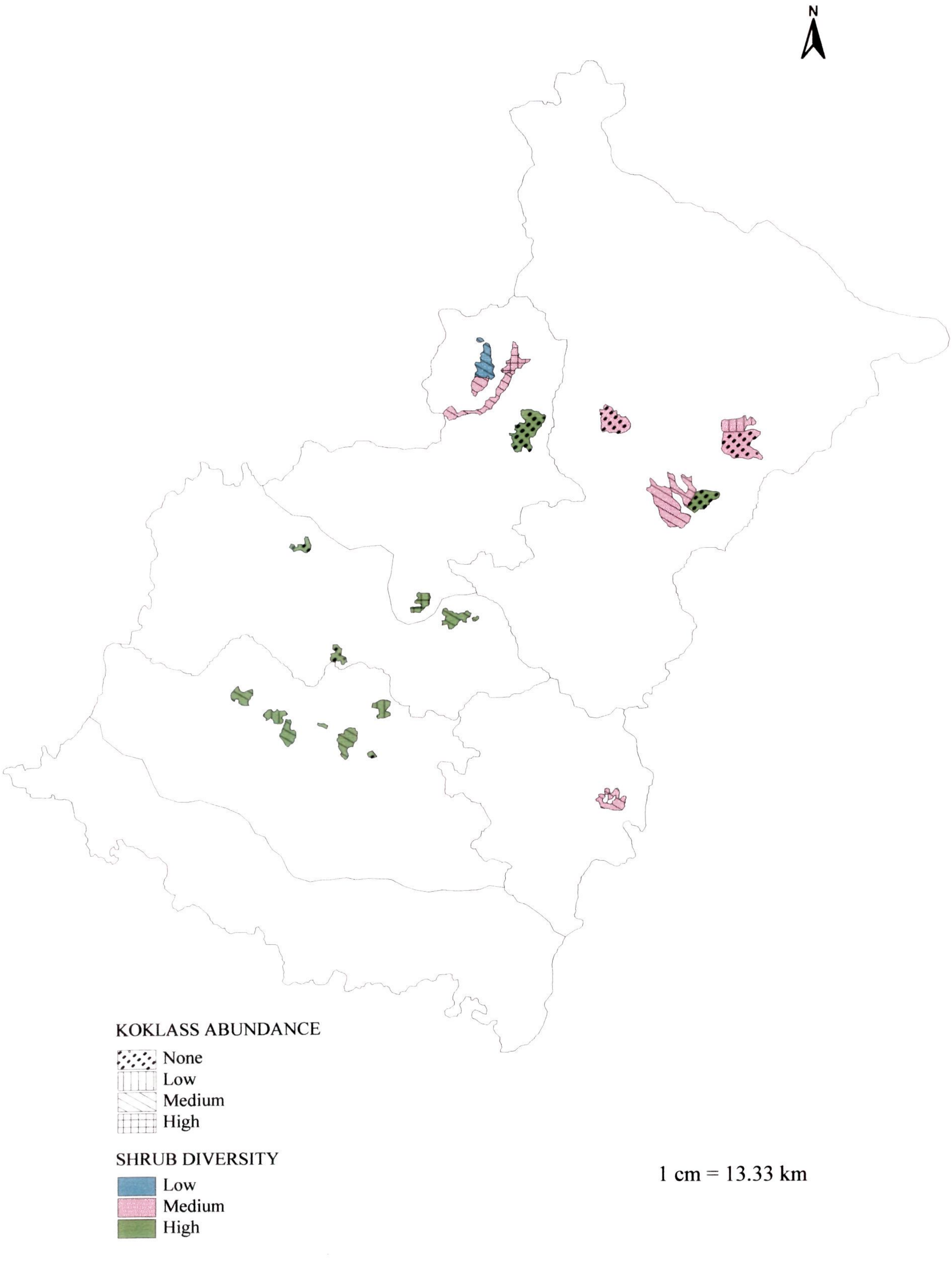
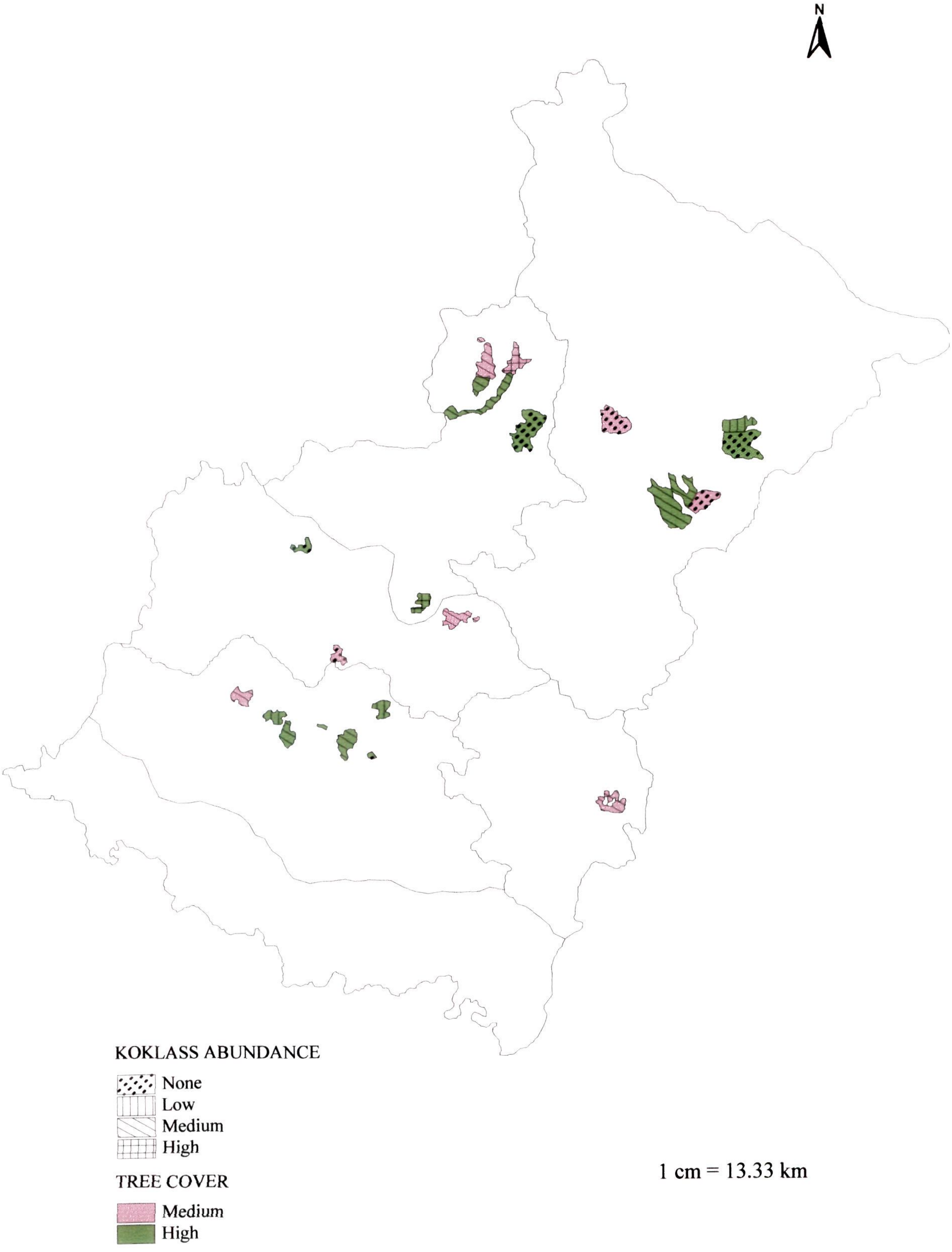


Fig. 4.5 Koklass abundance in relation to shrub diversity in Kumaon Himalaya.



1 cm = 13.33 km

Fig. 4.6 Koklass abundance in relation to tree cover in Kumaon Himalaya.

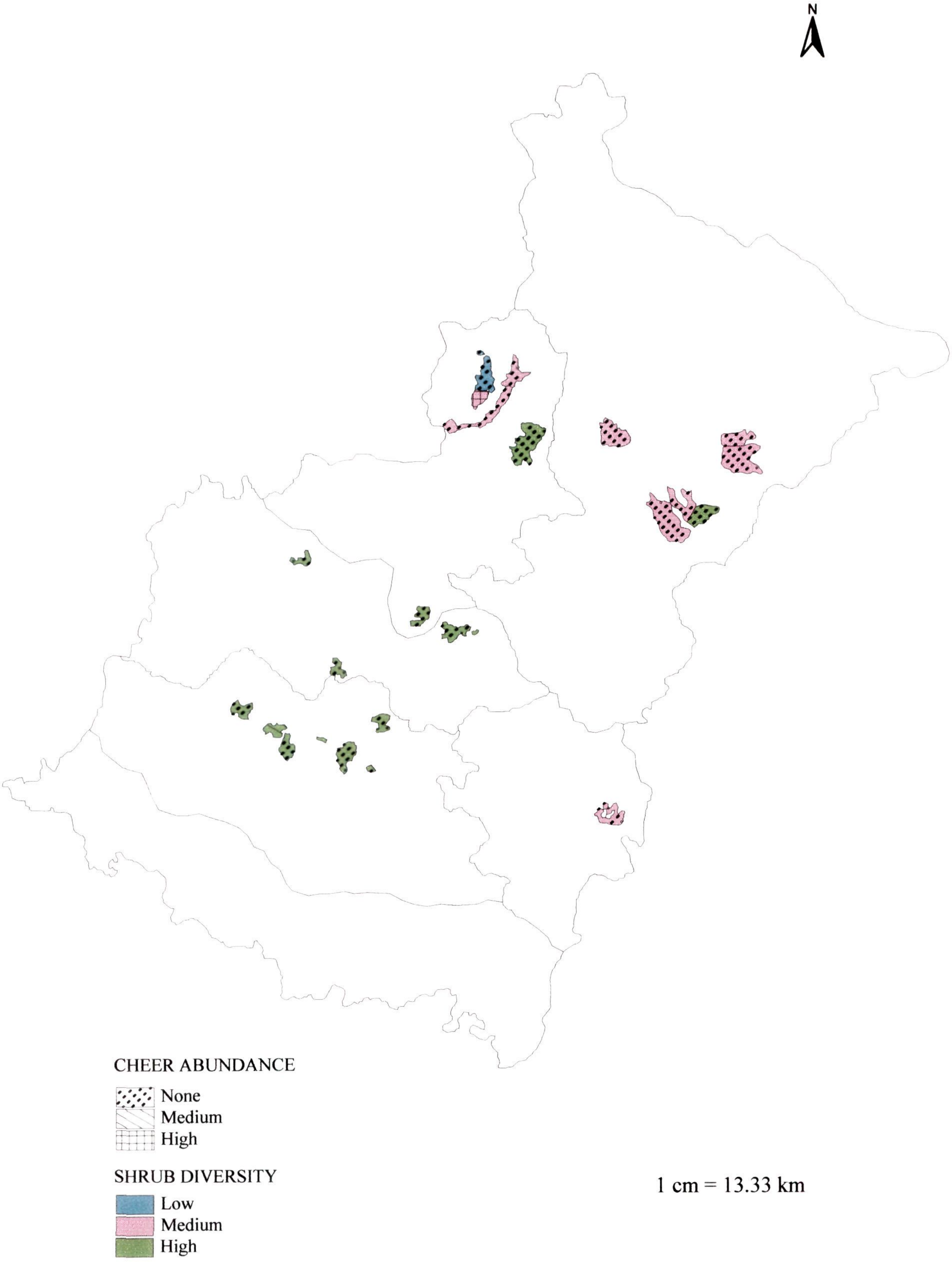


Fig. 4.7 Cheer abundance in relation to shrub diversity in Kumaon Himalaya.

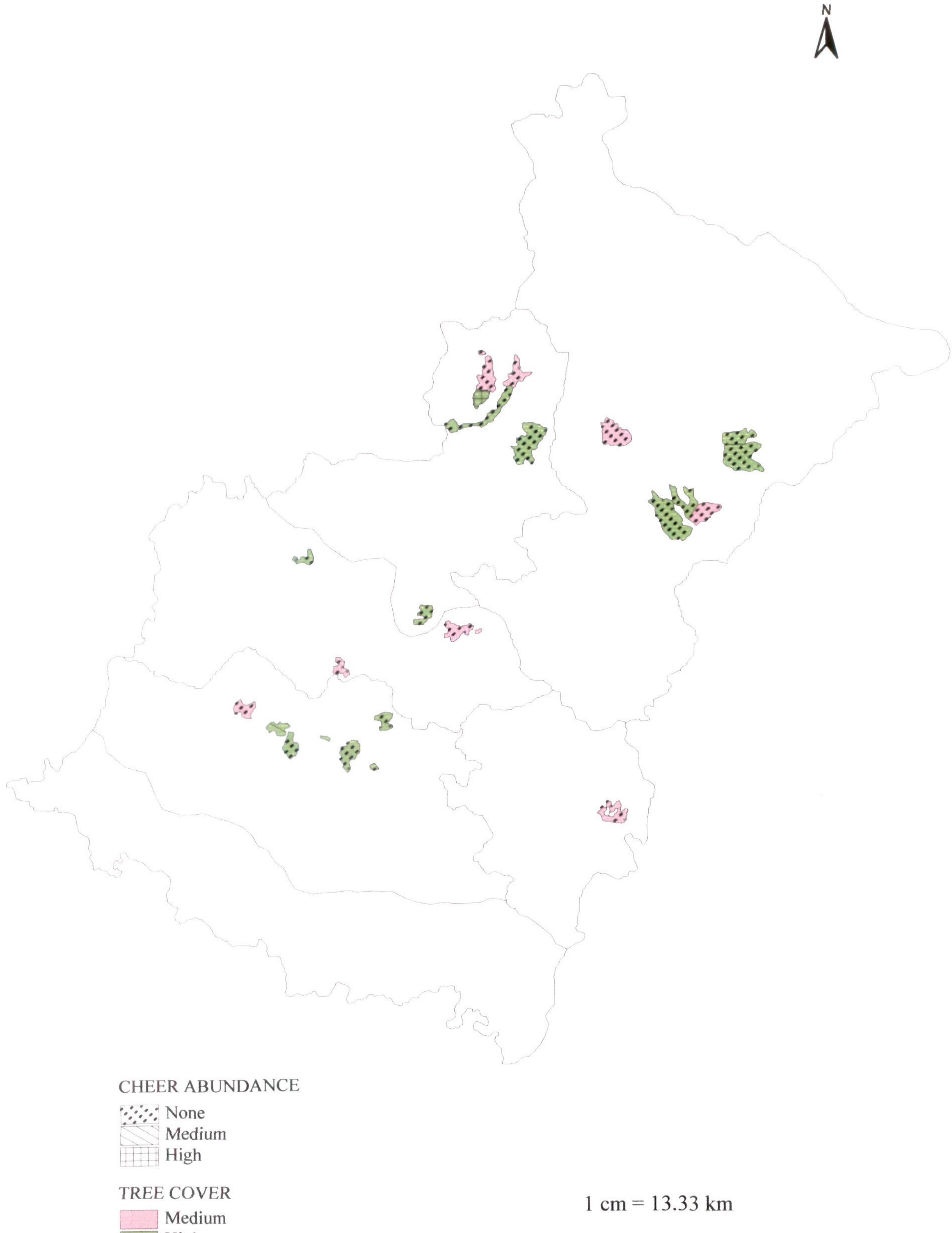


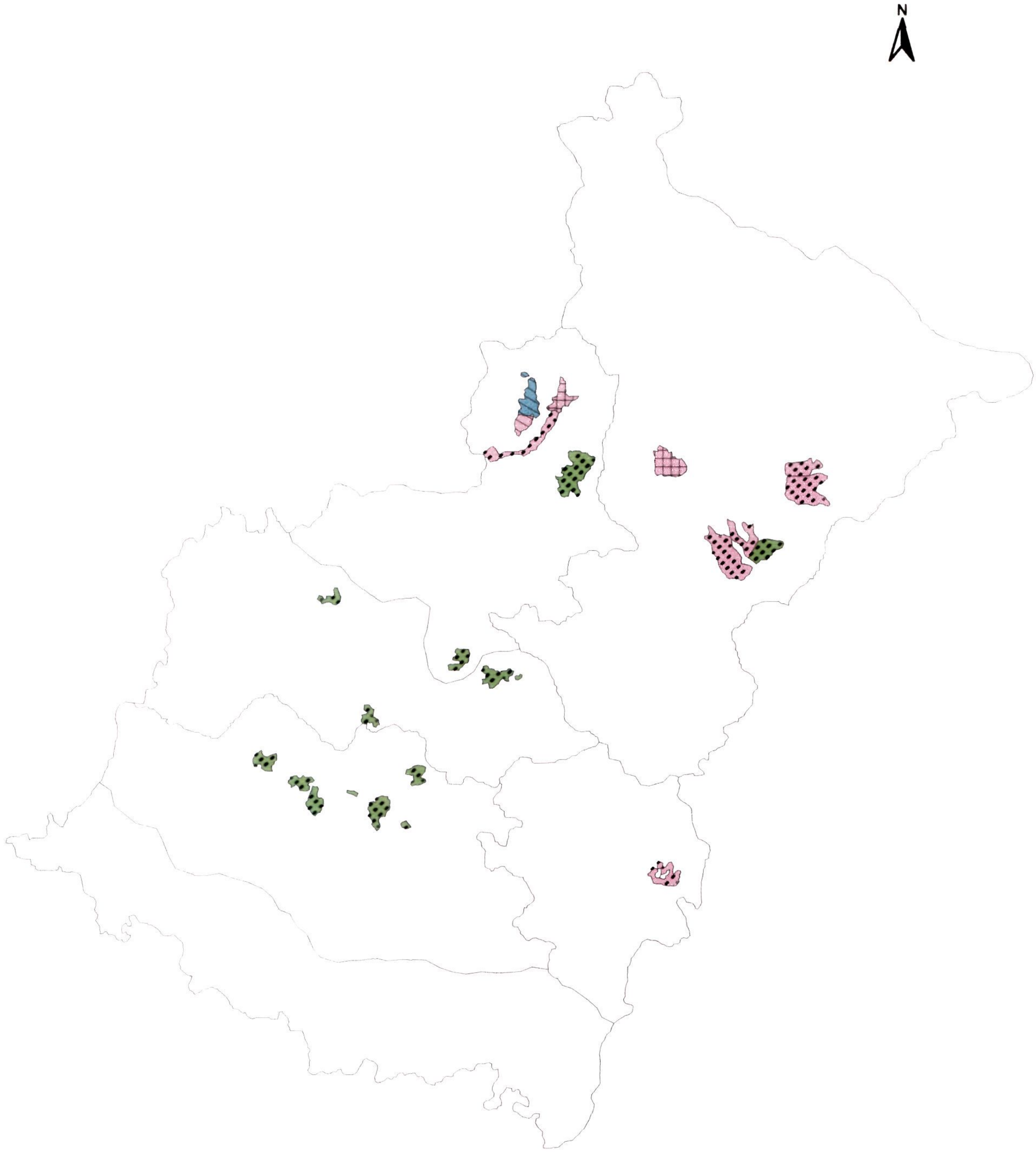
Fig. 4.8 Cheer abundance in relation to tree cover in Kumaon Himalaya.

$p < 0.01$) and shrub diversity ($r_s = - 0.523$, $p < 0.04$). Medium tree cover (Fig. 4.11) and medium shrub diversity (Fig. 4.12) were found at Pindari and Munsiary along with high Satyr abundance while at Sunderdunga shrub diversity was low and tree cover was medium together with medium Satyr abundance.

4.4 DISCUSSION

The distribution of animals is governed by certain factors, which include dispersal, habitat selection, interrelationships with other animals (predation, competition), temperature and moisture, and physiochemical factors (light, soil, water, fire etc.) (Kreb's, 1978). The surveys conducted in the Kumaon Himalaya revealed great variation in site characteristics. The sites varied in terms of habitat characteristics (Tables 2.2 and 2.3), anthropogenic dependency, and they suffered from general pressures from various means and ways (Table 8.1).

The surveyed areas, which were selected for this study, ranged between the altitude range from 1500-3500m and represented a sample unit of whole Kumaon. These sites were found to be in bad shape in terms of habitat condition. This was due to heavily populated human settlement in and around the surveyed forest patches. The people around these locations mainly depended on forest resources. The villagers used forest as nearest available resource, for timberwood harvesting, fuelwood collection, fodder for cattle and green manure, and also used forest area as cattle grazing ground and collection of other minor forest produce. Consequently, general habitat degradation was observed throughout the Kumaon.



MONAL ABUNDANCE
None
Medium
High

SHRUB DIVERSITY
Low
Medium
High

1 cm = 13.33 km

Fig. 4.9 Monal abundance in relation to shrub diversity in Kumaon Himalaya.

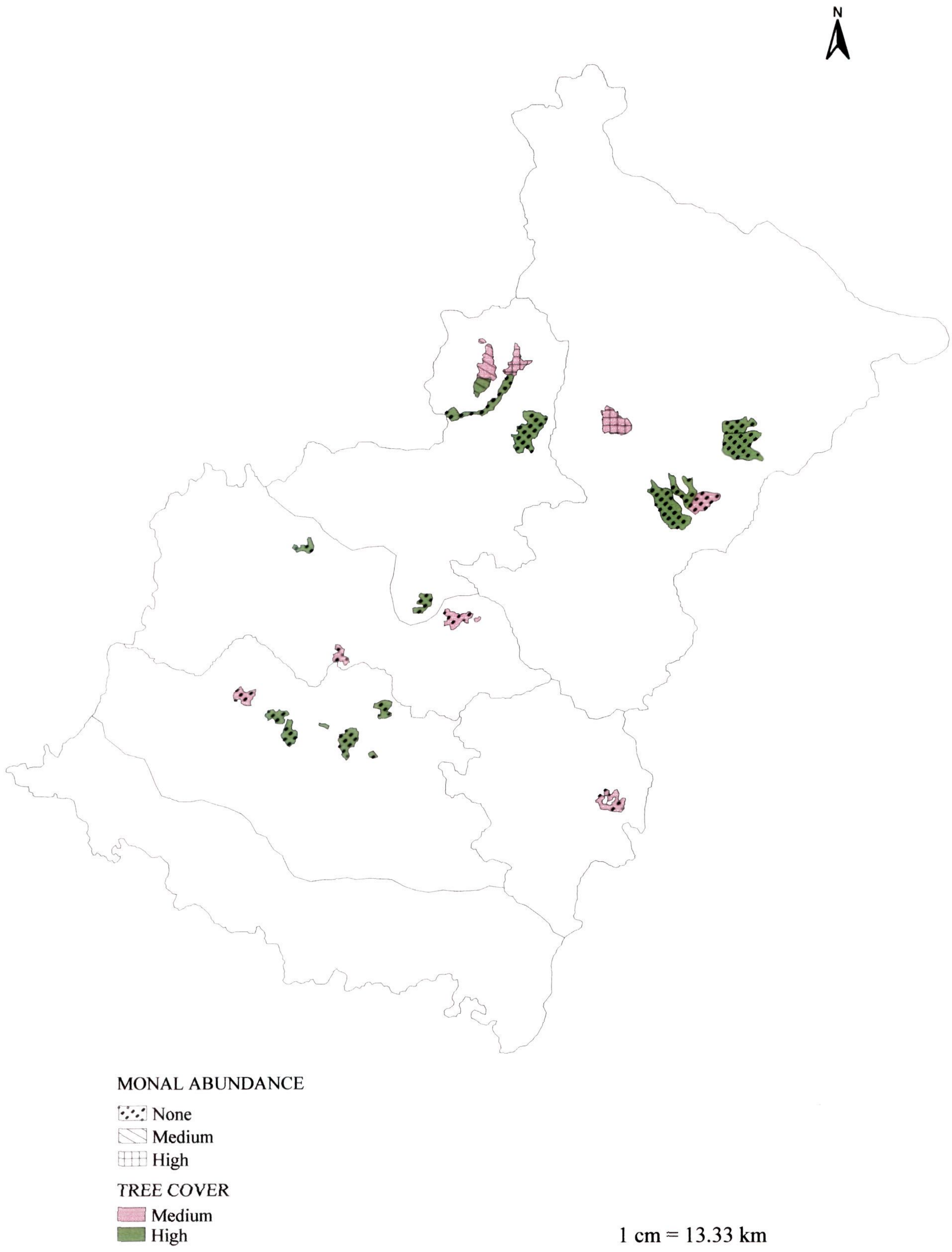


Fig. 4.10 Monal abundance in relation to tree cover in Kumaon Himalaya.

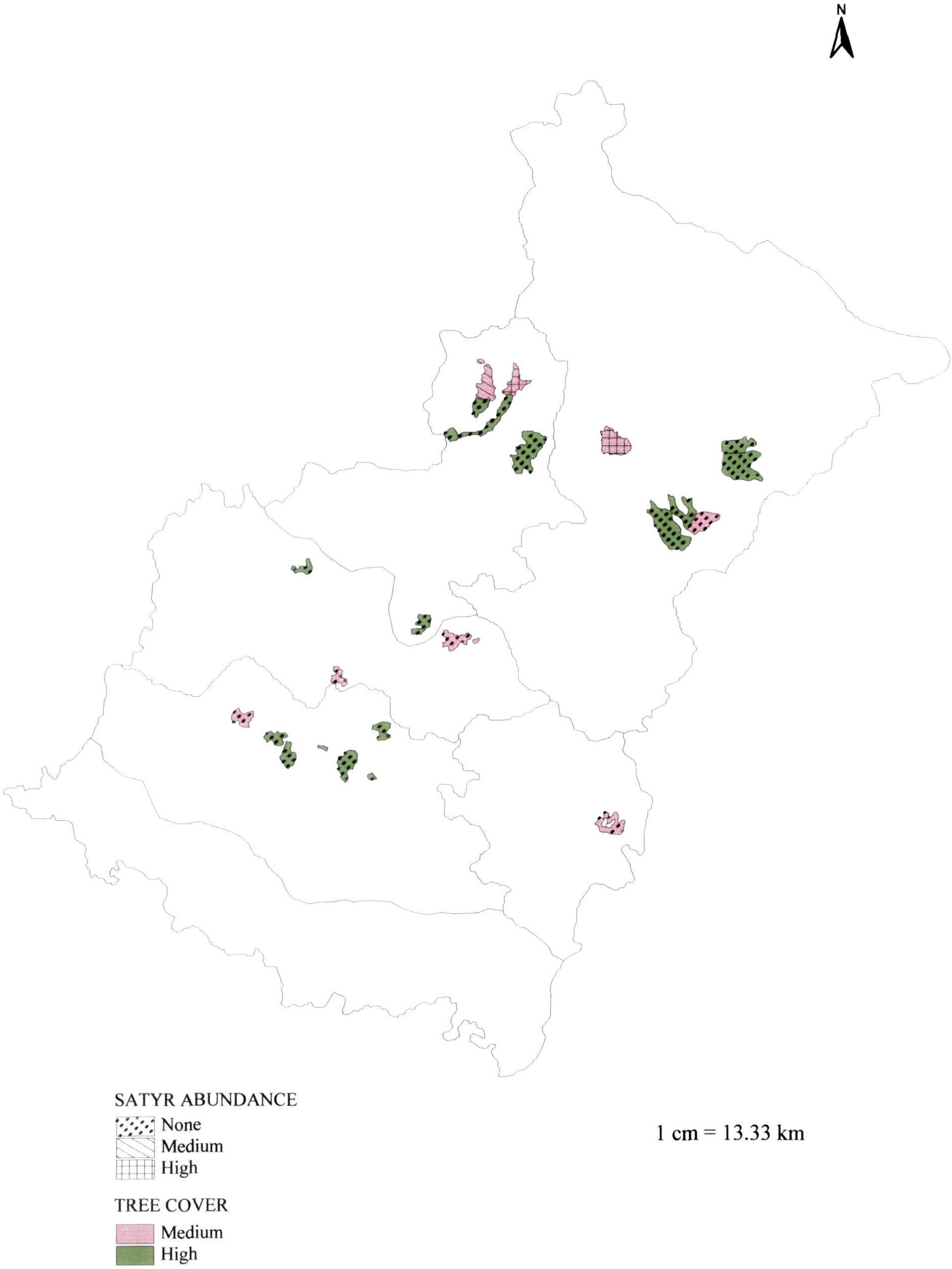


Fig. 4.11 Satyr abundance in relation to tree cover in Kumaon Himalaya.

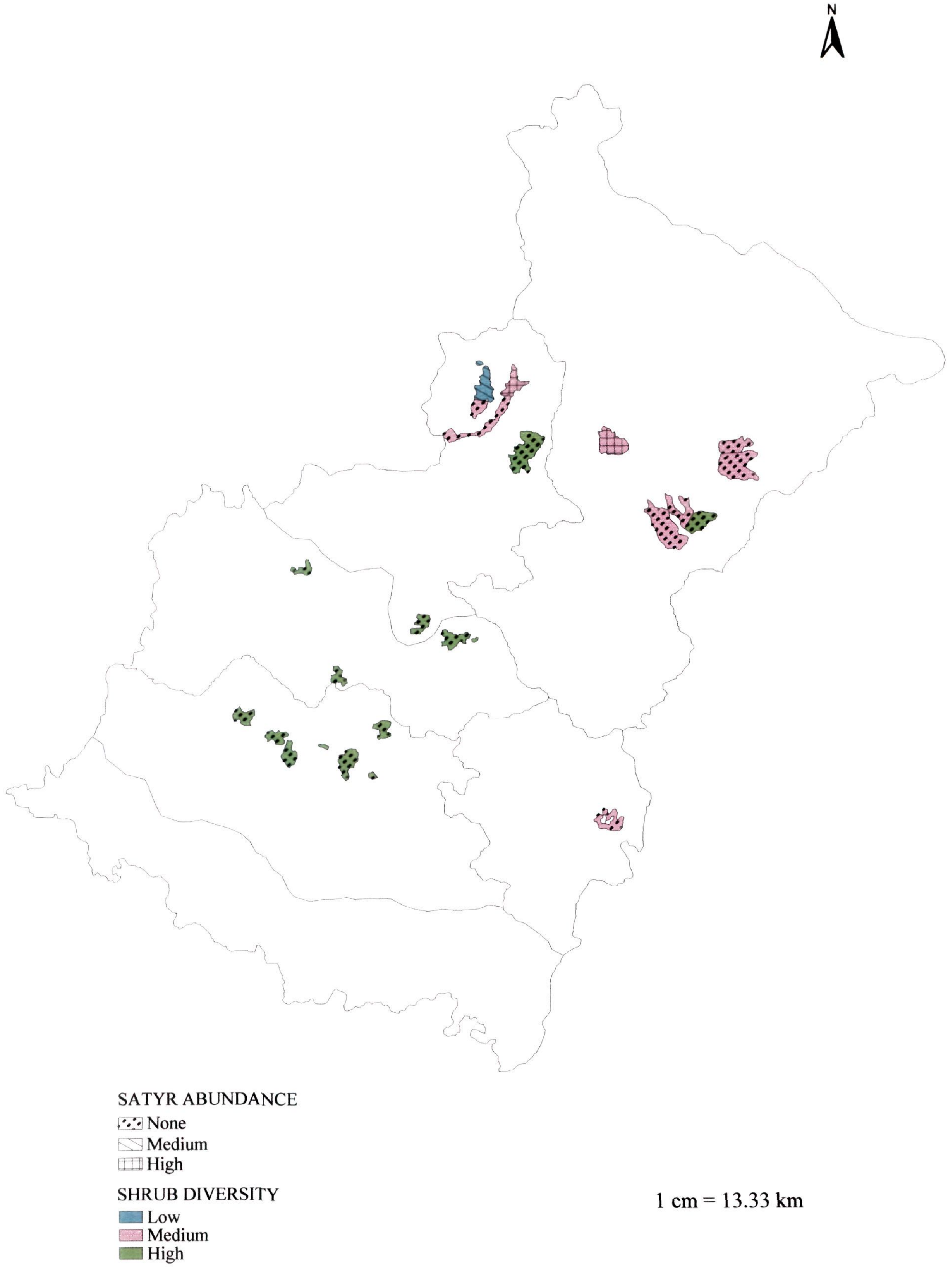


Fig. 4.12 Satyr abundance in relation to shrub diversity in Kumaon Himalaya.

The ecology of all the sites was determined by the effect of altitude, which mainly determine the climax vegetation (Mani, 1974). It is directly or indirectly responsible for governing faunal distribution in the Himalayas. Kumaon hills are part of Himalayas where the forest vary in vegetation composition with altitude and is bound to affect the distribution of different pheasant species also. Moreover, most of the pheasant species are said to be sedentary and show limited movements (Johnsgard, 1986). In general, altitudinal variation in distribution of different pheasant species like Whitecrested Kalij (245m-3050m), Koklass (2100m-3300m), Himalayan Monal- in Western Himalayas (summer- 2300–4875m, winter- 2000-2500m), Satyr Tragopan (2590-3800m) is wide and in case of Cheer the altitudinal movement (2200-3000m) is narrow (Grimmett *et al.* 1998). Hence, the altitudinal range as well as habitat types / vegetation composition of different sites of Kumaon restricted the existence of habitat specific species like Cheer, Himalayan Monal and Satyr Tragopan.

The results presented in this chapter suggest that distribution and abundance of different pheasant was not uniform. Out of five species (Kalij, Koklass, Himalayan Monal, Satyr Tragopan and Cheer) documented from the Kumaon region, Kalij *Lophura leucomelana* and Koklass *Pucrasia macrolopha* emerged as generalist species. The occurrence of these two species (Kalij and Koklass) was encountered from more locations as compared to other pheasant species like Cheer, Himalayan Monal and Satyr Tragopan. Kalij and Koklass were found at 14-20 (60% - 87%) locations while Cheer (including indirect evidences such as droppings), Himalayan Monal and Satyr Tragopan from 3 (13%), 4 (17%) and 3 (13%) locations of Kumaon respectively.

The variable occurrence of different pheasant species at various locations was due to the specific habitat requirement by various pheasant species. The distribution of Himalayan Monal used to be in more areas of Kumaon in the past as compared to reports (Young & Kaul, 1987 and Hussain *et al.* 1997), which showed the presence of this species at few places in Kumaon with a narrow range of its distribution. Irby (1861) has reported this species to be present in the Nainital district of Kumaon Himalaya. But species has disappeared locally from front ranges of Kumaon due to habitat loss and disturbance, and has been encountered in the remote places of Pindari, Sunderdunga and Munsiary areas only. These were the only sites in the studied region, which supported preferred undisturbed and continuous forested areas having oak and mixed coniferous forests with grassy glades, steep, rocky and grass covered slopes above the treeline for summer and winter habitat (Grimmett *et al.* 1998) for Himalayan Monal in Kumaon. Similar effect on the distribution of this species, due to habitat loss, in other areas of its distribution range has been observed. It is stated that (Wilson in Hume & Marshal, 1879) Himalayan Monal, which formerly occurred in the front ranges of Simla and Mussoorie, has disappeared from these areas.

Information provided by Hume & Marshal (1879) suggested Cheer to be patchily distributed although described it as common in Kumaon, Garhwal, and as far as west as Chamba in Himachal Pradesh. It is presently listed as endangered in the Red Data Book (IUCN, 1994). The overall range of this species has contracted. The distribution of this species supported presence of Cheer at three locations (present study) with a possible narrow range from Vinaiyak-Kilbery areas to Mukteshwer (Rasool, 1984). Within this range, there are places such as Bhowali-Bhimtal and Padampuri & Jilling where locals had confirmed the presence of Cheer in these areas. I have collected droppings and feathers from the roosting site told by a local from a place, which is in between Bhimtal and Jilling estate but this site was not chosen as the survey site so further search was not initiated. Another narrow belt of Cheer distribution within the Kumaon falls between Pindari valley (Dwali and Wachham) and Sobala (one of the sites surveyed in Askot Wildlife Sanctuary). The species was recorded from Wachham and Pindari as Kaul (1989a) has recorded. The species was always encountered with common habitat features at steep grass-clad hillside with scattered trees, permanently with rocky crags. Some convincing information regarding the presence of Cheer at other places was also came into light but these locations could not be surveyed due to limitation of time. The possible reason for the contraction and in distribution and local extinction of Cheer from many places of its former range where it used to be present fairly in good numbers (local's personal) for its preference to long grass (Gaston, 1981) might have contributed to the species decline, particularly in the lower parts of its range in the Kumaon. Otherwise the species is still surviving in small population at many locations within the Pindari valley and at some other locations of Kumaon Himalaya.

The distribution of Satyr Tragopan matched with the distribution range of Himalayan Monal in Kumaon. This species was encountered in those areas where Monal was distributed. The absence of this species at Wachham may be due to the reason that the habitat condition of Wachham was in degraded state and here forest areas started at the altitude from 2700m coupled with scattered human habitation covering large degraded area. The locals of Wachham claimed presence of this species with rare sighting at higher elevation in the forest ranges of Wachham reserve forests during winters only.

This could be due to the seasonal altitudinal movements of the species (Grimmett *et al.* 1998) while other sites of Kumaon i.e Pindari, Sunderdunga and Munsiary where the species was encountered presented clumped human population. Moreover, these were the only areas, which provided suitable habitat condition for Satyr Tragopan having adequate area of moist oak forest and Rhododendron forest with undergrowth and bamboo clumps shrubberies on steep hillsides and narrow ravines, and mixed coniferous / broadleaved forest free from disturbance (Grimmett *et al.* 1998). The other surveyed sites were devoid of specific habitat conditions required for Satyr Tragopan existence, though Satyr Tragopan has been reported to be present (Irby, 1861) in the Nainital district in the past century, which supported the existence of suitable habitat with wider distribution range of this species in Kumaon.

Similarity in sites on the basis of pheasant species composition divided all the surveyed sites into nine groups. The compositions of species ranged from nil to five species in each group. These groups represented similarity in pheasant species composition as well as supported more or less similar habitat condition suitable for various pheasant species. Kalij and Koklass being generalist species (Hussain *et al.* 1997) in Kumaon formed a group of sites Gandhura, Majtham, Daphiadhura, Pandavkholi, Binsar, Mukteshwer, Gager, Maheshkhan, and Kunjakharak. All these sites were found to be in highly degraded state in terms of anthropogenic interference but relatively intolerant nature of Kalij and Koklass towards habitat disturbance due to various anthropogenic activities (Gaston, 1981) represented wider distribution of these species in Kumaon while sites Sunderdunga and Munsiary formed another group by having Koklass, Himalayan Monal and Satyr Tragopan. These sites provided less disturbed continuous oak and mixed coniferous forests and areas leading to sub-alpine and alpine zone suitable for Monal and Satyr Tragopan (Grimmett *et al.* 1998). Group of sites Kilbery, Jageshwer, Mechh and Dhakuri formed a unique pheasant species composition by having a single pheasant species in the form of Koklass. This does not mean that these sites were devoid of other pheasant species found in Kumaon. The other pheasant species could not be encountered due to some other reasons at these sites.

Pindari and Wachham formed separate cluster by having maximum pheasant species encountered in Kumaon. These two sites represented unique habitat. Both the sites extended upto varying altitude range from 1800m to > 7000m. As altitude determines the vegetation climax (Mani, 1974), these sites provided different habitat types required for different pheasant species. Moreover, these sites provided exclusive Cheer habitat in whole of Kumaon. The other sites like Gasi and Sitlakhet formed another group where no pheasant species was encountered. These sites were found to be in highly disturbed state in terms of excessive disturbance activities like more cattle grazing, lopping of trees leaves and branches, large number of human settlement in and around these patches and frequent visits by local inside the forest was observed, which might have affected the species presence and might have compelled the species to become locally extinct from these areas.

Actual density estimates (groups / unit area) for different pheasant species encountered in Kumaon could not be generated. The reason being, most of the assumptions of the line transect method (Burnham, 1980 and Bibby *et al.* 1992) could not be fulfilled due to prevailing field conditions at the surveyed sites of Kumaon. Though this method was adopted in the initial surveys of premonsoon 1996 at few locations as a test to generate actual density estimates prior to going for extensive surveys in whole of Kumaon. But all the assumptions of the line transect method could not be ruled out due to unlikely field condition.

In later surveys, I found monitoring existing forest trails a suitable alternate method (Kaul & Ahmad, 1993 and Sathyakumar, 1993) for estimating relative abundance estimate of different pheasant species of Kumaon. Distribution studies indicated that encounters with different pheasant species were not uniform throughout the Kumaon. The fluctuation in the encounters across the surveyed locations was mainly due to variations in the vegetation parameters and threat factors. There may be some other reasons also for variable encounters of different pheasant species. For instance, the time frame spent at each location may not be enough for pheasant species, because of their secretive nature, to be encountered at each site or they might have not been encountered for some other reasons.

Among five pheasant species encountered in Kumaon, only Kalij and Koklass were distributed throughout the Kumaon and they were encountered or/heard at 15-20 sites out of 23 surveyed sites. The other species like Cheer, Himalayan Monal and Satyr Tragopan were encountered at few locations (Table 4.4). The study revealed that the abundance of all the pheasant species was mainly governed by habitat factors. The abundance predictor models produced out of this study for Kalij and Koklass indicated that the Koklass abundance was positively correlated with livestock population and Koklass heard during call count. This indicated that Koklass preferred pristine habitat where grazing occurs for short duration of the year and human does not inhabit the area throughout the year. Severinghaus (1990) in his study at Dunga Gali and Shorgan in

Pakistan found similar habitat condition inhabited by Koklass in fairly good numbers. During my intensive ecological studies at Binsar Wildlife Sanctuary, the abundance of Koklass was more on the trails which were frequently used by cattle for grazing while in Pindari the abundance was more on the trails which were being used by nomads and pastorals for grazing their cattle and sheep & goats during summer and monsoon seasons of the year but they did not inhabit the area permanently. So the model concluded a general statement about the occurrence of Koklass and the species would be more in areas, which are having, pristine habitat associated with seasonal grazing without human presence while abundance of Kalij was determined by habitat factors only. None of the disturbance factors affected the presence of Kalij. Being relatively tolerant of disturbance and occurring in secondary scrub as well as in climax forest (Gaston, 1981), it was found throughout the Kumaon in fairly good numbers. The habitat factor, herb diversity had negative effect on Kalij abundance and the species in the areas like Kunjakharak, Mukteshwer, Majtham and Duk beat etc was encountered with low number of groups. Other factors such as increased herb diversity and herb richness favoured the species presence in more numbers at other sites.

The GIS analysis performed on certain habitat factors (tree cover, shrub diversity, herb diversity and herb richness), that have direct effect on pheasant species abundance (Severinghaus, 1990 and Gaston, 1981) showed no association in Koklass and Cheer abundance while some parameters had shown significant association with abundance of Kalij, Monal and Satyr Tragopan. The neutral effect of a set of habitat parameters on Koklass abundance accomplished out of this study has been reflected in the results and the sites holding the species supported their presence in good numbers. Cheer did not show any association with any habitat parameter in this analysis due to the reason that the species was encountered at two sites only with few sightings and large data set for Cheer could not be generated to predict a model comprising of a set of habitat parameters which may be responsible for bringing variations in the abundance of this species. Kalij abundance was associated with increased tree cover and Maheshkhan and Binsar had closed canopy forest and supported more Kalij group in these areas during the study period. Abundance values of Monal and Satyr showed negative association with tree cover and shrub diversity within their narrow distribution range in Kumaon. The Monal occupied open forest canopy areas in the Pindari, Sunderdunga and Munsiary. These were the only sites, which supported the typical habitat conditions where Monal was encountered frequently and remained there throughout the year. Whereas Wachham or Dhakuri supported occasional sightings of Monal during winters when the upper areas experienced heavy snowfall. Most of the time, Satyr was encountered at the edge of the forest leading to sub-alpine meadows but the habitat requirement matched with the habitats of Monal and Koklass within their distribution range and the species has been encountered once feeding with groups of Monal and Koklass near Dwali in Pindari valley.

CHAPTER 5

ECOLOGICAL STUDIES

5.1 INTRODUCTION

Presumably since man started foraging for animals and plants in the bushes, he has realised that different organisms live in different places and that different birds are found in different habitat (Cody, 1985). Birds primarily utilize any habitat for food, shelter and nesting. While some birds utilize same habitat for all purposes. Thus a bird may be found utilizing a range of habitats for different purposes. This can vary with the season as well. For instance, forest birds often forage along the edges or in the adjacent open habitats. Hill birds move to lower elevations during rains and the colder seasons (Ali & Ripley, 1987).

Determination of habitat occupancy of bird population is central to consideration of community and niche relationship, as well as to intelligent conservation and management of those population or habitat (Wiens & Rotenberry, 1981). Since the suggestion of Lack (1933) and others nearly 50 years ago that birds may select the habitat they occupy on the basis of the structural configuration or physiognomy of the habitat, and also most of the studies of bird-habitat relationships have emphasized such structural features (see Hilden, 1965 and Wiens, 1969).

Each species of bird requires a patch of vegetation with a particular profile for its selected habitat, and the variety of patches within a habitat determines the variety of bird species for the complexity of associated bird communities (Anderson, 1979). Habitat is thus the templet for ecological and evolutionary process (Southwood, 1977). Information about habitat relationship with bird species/bird group is essential to any full understanding of the pattern of life history, adaptation, or behaviour of a species, features that are expressed in modern ecology.

Habitat variation has profound consequence on the pattern that is observed, and to begin with to distinguish such alternative requires detailed knowledge of that habitat distribution of species and species assemblages. Lack (1940, 1944) emphasized the importance of habitat segregation in closely related species and of habitat diversity in the multiplication of congeneric species.

Kumaon represents a significant unit in the Himalayas in terms of pheasant species composition. No detailed ecological study has been done so far for this bird group except studies conducted for Cheer (Kaul, 1989a) and Whitecrested Kalij (Ahmed, 1995) in this region. The theme of this chapter is to answer the questions such as-

- How Kalij, Koklass, Himalayan Monal, Cheer and Satyr Tragopan are ecologically separated from each other in their distribution range in Kumaon.
- Are there differences in habitat utilization by different pheasant species within and between different seasons of the year and to what extent?
- Which microhabitat attributes were exclusively required by different pheasant species for various life activities within and between different seasons of the year.

So that a comprehensive conservation strategy could be formulated for all pheasant species.

5.2 METHODOLOGY

5.2.1 Data collection

Data were collected through extensive surveys and intensive ecological studies.

5.2.1.1 *Extensive surveys*

Three surveys were conducted during premonsoon (March-June) & postmonsoon (September-December) seasons of 1996 and postmonsoon season of 1997 at the sites mentioned in chapter 4. Direct sightings as well as indirect evidences such as droppings or feathers were considered as presence of species. Trail monitoring and random search was made to encounter different pheasant species. Each sighting of a species was considered as one group and if a group of birds consisted of more than one species then the individuals of each species was considered as one group of that species. Likewise, indirect evidences such as feathers or droppings were also considered as one group and if it consisted these evidences of more than one species then feathers or droppings were considered as separate group for different species. At each direct sighting or/indirect evidences found, following records were made: a) Identification of species, b) General angle of slope, c) Habitat types, d) Weather condition. Besides, random search of the area was also made to document the species, if, it anyhow, has not been encountered/or recorded during trail monitoring. Same details were recorded which were recorded on the trail monitoring during surveys.

During the trail monitoring, vegetation was also quantified at the spot where the pheasant species was sighted. Ten-tree method (Rodgers, 1988) was employed to quantify the tree layer. Nearest ten trees with their species and number were recorded for species density, species diversity and species richness estimates. The distance of 10th and

11^{th} tree from the sampling point was measured and recorded to calculate the area of the sampling plot. Shrub layer was quantified in 2m radius circular plot within the ten tree-sampling plots. The species and the number of different shrub species were recorded for the estimation of density, diversity and species richness. The ground vegetation (herbs and grasses) was quantified within $1m^2$ quadrate placed within the sampling plot where the pheasant species was sighted. The number of herbs and grasses with their species were recorded to estimate their density, diversity and species richness. The tree cover was measured by using gridded mirror of 10 inches x 10 inches dimension. The mirror was further divided into 25 equal grids of 2 inches x 2 inches each. It was placed horizontally at the stomach height of observer. The images ≥ 50% of foliage within the grids were only taken for the tree cover estimate. The grids covering < 50% foliage images were discarded. The tree cover was measured in terms of percentage. Shrub cover was measured by ocular estimation within 3m radius circular plot in terms of percentage.

Ground cover (grass, herbs, litter, rock, bare ground and withered stone) was measured by using line intercept method (Canfield, 1941). A meter tape was laid on the ground and twenty observations were recorded from there. The intercepting materials (grass, herbs, litter, rock, bare ground and withered stone) at each 5cm interval were recorded. The intercepting materials on the basis of frequency of occurrence were later converted into percentage.

Assessment of different disturbance factors was done on ordinal scale where 1 represented low disturbance, 2 represented medium disturbance and 3 represented high disturbance. The disturbance factors cutting, lopping, and dung piles were assessed by counting number of cut trees, lopped trees and dung piles within the 10m radius circular plot where the bird was sighted. Grazing was measured on ordinal scale of low, medium and high.

5.2.1.2 *Intensive studies*

Two sites were selected for intensive monitoring. These were Binsar Wildlife Sanctuary (hereafter BWS) and Pindari Reserve Forest (hereafter Pindari). BWS had two species of pheasant while Pindari had maximum number (five) of pheasant species, out of all surveyed sites in Kumaon. To obtain ecological models for the conservation of different pheasant species in general and habitat in particular, these sites were selected for intensive ecological studies.

a) Binsar Wildlife Sanctuary: Two main habitat types were selected in BWS. Four existing forest trails, two in oak habitat and two in oak-pine, were used for monitoring. All the trails were of varying lengths. The aim behind selecting the trails in different habitat types was to observe the habitat requirement of different pheasant species during different seasons of the year. Regular monitoring was done on each trail. The monitorings of trails were performed during morning hours during premonsoon season while morning and evening monitorings were performed during postmonsoon season only. Similar habitat data were collected which had been recorded for direct sighting/indirect evidences of pheasant species during the surveys of Kumaon. Call count was also conducted in BWS to estimate abundance of calling Koklass. For this, three vantagepoints were selected. These points were nearly at crow distance of one km apart and positioned in a triangular fashion. These points faced valleys and made hearing calling individuals easy from as much distance as possible. Successive dawn chorus counts were made till no chorus was heard at the vantagepoints. The methodology for data collection for this was same as it was adopted for call counts during the surveys of Kumaon Himalaya.

Same habitat attributes data were collected on each monitored trail, which were collected for general vegetation sampling during surveys of Kumaon. The methodologies for this have been discussed in detail in chapter 3.

b) Pindari Reserve Forest: Four trails were selected for intensive monitoring in Pindari. These trails were selected between altitude range from 2200-3300m to document all the pheasant species, which were to some extent separated from each other within the same season due to gradients of altitude. Out of four trails selected for monitoring, two were in Oak habitat and one each in oak-coniferous and mixed habitat types. Monitoring of each trail was performed in the morning hours (before sunrise) regularly. Same methodology and habitat parameters were recorded at each encounter with different pheasant species here too which were recorded at BWS during trail monitoring. Regular call counts could not be performed at Pindari due to limitation of habitat conditions and location of the only place for the stay where this study was conducted. All the other data sets and the methodologies for data collection were same, which were adopted for BWS.

5.2.2 Data Analyses

5.2.2.1 *Ecological separation of different pheasant species*

The Discriminant Function Analysis (DFA) was applied for five pheasant species to separate them on the basis of habitat attributes and various disturbance factors in Kumaon Himalaya. It is a multivariate technique that can aid in distinguishing between different species according to their characterization by a series of environmental attributes. The direct sighting data were organized into species-habitat variables matrix and was subjected to stepwise discriminant function analysis. Density for tree, shrub, herb and grass layers was calculated following Greig-Smith (1984) for each bird-sampling plot. The tree, shrub, herb and grass diversity was calculated by using Shannon-Weiner's diversity index following Magarrun (1988) and tree, shrub, herb and grass richness for these plots was calculated by above mentioned Margalef's species richness index. The variables were adjusted by suitable log (ln) and arcsine transformation and further standardized to bring normality in the magnitude of variation each variable possessed. DFA is a sensitive form of analysis designed for data containing limited overall variance and an equality of dispersion of groups (species) on each habitat variable (Hope, 1968). Direct sighting and habitat variable matrix was further subjected to Pearson-product moment correlation analysis (two-tailed) to check for intercorrelation. Table 5.1 provides list of variables with details of transformation and variables discarded from inclusion in discriminant function analysis (DFA). The DFA analysis was performed on matrix of 350 sighting x 14 habitat variables. The discriminant function analysis calculates a vector (a line) that maximizes the distance in n-dimensional space between the groups being examined. There is a discriminant function score or value for each group on this vector. The means of the habitat variables are multiplied times of their appropriate coefficients. The summation of these products yields the discriminant function values (Conner & Adkisson, 1976). DFA (Nie *et al.* 1970) was used to compute

Table 5.1 List of variables used in Discriminant Function Analysis.

S No.	Variables code	Variables	Transformation
1	ALT	Altitude in m	log & standardised
2.	SLP	Angle of slope	log & standardised
3.	TTR	Tree density	log & standardised
4.	TRIC	Tree species richness	log & standardised, discarded
5.	TCR	% canopy cover of trees	arcsine & standardised
6.	TDIV	Tree species diversity	log & standardised,discarded
7.	SSD	Shrub species density	log & standardised, discarded
8.	SDIV	Shrub species diversity	log & standardised
9.	SRIC	Shrub species richness	log & standardised
10.	SCR	% cover of shrub	arcsine & standardised
11.	SHT	Shrub height in cm	log & standardised
12.	HTR	Herb density	log & standardised
13.	HDIV	Herb Species diversity	log & standardised, discarded
14.	HRIC	Herb species richness	log & standardised,discarded
15.	GTR	Grass density	log & standardised
16.	GDIV	Grass species diversity	log & standardised
17.	GRIC	Grass species richness	log & standardised,discarded
18.	GT	% cover of grass	arcs. & standardised
19.	HR	% cover of herb	arcs.,standardised, discarded
20.	LT	% cover of litter	arcs. & standardised
21.	RK	%cover of rock	arcs., standardised, discarded
22.	BT	% of bare ground	arcs. & standardised

an index of niche separation (M`Closkey, 1978). This was the F-ratio of between-to-within species variance in habitat use.

5.2.2.2 *Macro habitat use of different types during and between the seasons by different species*

A series of Chi-square tests were performed to see the differences in the groups of different species encountered in different habitats within the season, and between different seasons. A series of contingency tests were also performed for each species to pin point the exact habitat in which the groups were encountered more or less than expected between the seasons. All the tests were performed for both the intensive study sites i.e. Binsar Wildlife Sanctuary and Pindari following Fowler & Cohen (1986).

5.2.2.3 *Micro habitat use of different pheasant species between different seasons*

The presence of a species in a particular habitat in the area may be influenced by several variables acting together than a single variable. Keeping this in view, the quantified habitat variables recorded from direct sighting and indirect evidences plots of different pheasant species were taken into account for habitat use and these were compared with the available habitat. Similar species-habitat parameters matrix was generated as it was generated for discriminant function analysis. Separate matrix for each species was made and it was considered as habitat used (utilized) by that species. General vegetation sampling on the trails was considered as available (availability) habitat for pheasant species. Sampling of vegetation around direct sighting was considered as utilized habitat. Both the data sets were combined to prepare a species x habitat matrix. The matrix was subjected to suitable log and arsine transformation and later it was standardized following Zar (1984) to bring normality for valid analysis. Habitat use was evaluated by comparing the available habitats, with the number of observations of birds of each species. Factor analysis, which identifies a relatively small number of factors that can be used to represent relationship among sets of many interrelated variables (Norusis, 1990) was used for this. Later a logistic regression analysis was performed using extracted factor scores from the analysis to estimate the probability of correct classification of pheasant species plot (utilized) and general available habitat plot (available). Non-parametric Mann-Whitney U test was also performed to see whether there was any difference in available habitat and utilization of the variables by different pheasant species. The analysis was performed for premonsoon and postmonsoon seasons for both the intensive sites for all pheasant species separately. All the statistical tests were performed by computer Software package SPSS (Norusis, 1990), for Windows release 7.5.

5.3 RESULTS

5.3.1 Ecological Separation for different pheasant species

The importance of individual habitat characteristics as predictors of which pheasant species will occupy a particular environment is summarized in Table 5.2. This table is based on Bargman's extension of the discriminant analysis program, which computes the relative importance of variables in their ability to distinguish between populations. All but one are significant at the five percent level and the majority are highly significant ($p < 0.000$) and contribute to the separation of species. Particularly, the

Table 5.2 U statistics and univariate F ratios with percentage levels of probabilities for each of the 14 variables included in the Discriminant Function Analysis (4 & 345 degrees of freedom).

Variables	Wilk's lambda	F ratio	Significance
Altitude	0.435	112.09	0.00
% Bare ground	0.981	1.684	0.15
Grass diversity	0.973	2.935	0.05
Grass density	0.971	2.553	0.03
Herb density	0.913	8.186	0.00
% Litter	0.946	4.939	0.00
Shrub cover	0.89	15.361	0.00
Shrub height	0.935	6.029	0.00
Shrub diversity	0.782	24.054	0.00
Slope	0.879	11.878	0.00
Shrub richness	0.941	5.443	0.00
Tree cover	0.836	16.968	0.00
Tree density	0.864	13.548	0.00
% Grass cover	0.883	11.483	0.00

variables altitude, shrub diversity, percentage of tree & shrub cover, tree density and percentage of grass cover co-vary with species occurrence where as others do not. The variables with least discriminating powers and having least effect on species distribution was percentage bare ground, a reflection of the fact that no pheasant species was found in the areas without any vegetation.

The analysis produced four functions DF1, DF2, DF3 and DF4 accounting for 100% variation between the species. The four functions DF1, DF2, DF3, and DF4 explained 85.8%, 8.15%, 3.8% and 2.3% of variance respectively. The last three DF extracted less than 10% of variance and therefore it may be considered by chance (Table 5.3). The first discriminant function represented variation in altitude from low to high. The second function described vegetation components. The areas having more percentage of grass cover and low herb density were represented by second function while function third represented areas from open to close canopy forest with simultaneous increase in percentage of cover in shrub layer. The cumulative effect of these three functions accounted for 97.7% of variance, which together explained the variation in the habitat selection by five pheasant species in increasing order of their magnitude. Figure 5.4 provides the species centeroids in relation to the three functions in three-dimensional space and separately. Figure 5.1 is a plot of function 1 with respect to function 2, which clearly separated all the five species. Kalij was associated with the areas having low percentage of grass cover and with enough herb density at low altitude. Kolass preferred areas having very low grass cover and abundant herb density at middle altitude. Cheer pheasant was associated with the areas having high percentage of grass cover with limited number of herbs at middle altitude while Satyr Tragopan was present in the areas

Table 5.3 Standardised weights for 6 variables from a Discriminant function analysis of 5 species. Percentage of total variance extracted by each DF is noted in the column headings.

Variables	**DF 1** **85.8%**	**DF 2** **8.1%**	**DF 3** **3.8%**
Altitude	0.992*	0.107	-0.438
Herb density	-0.189	-0.664*	-0.119
Shrub cover	0.042	-0.257	0.781*
Slope	0.300	0.160	0.067
Tree cover	-0.392	0.098	0.574*
% Grass cover	-0.076	0.732*	-0.005

* Variable showing largest absolute correlation between each variable and any Discriminant function

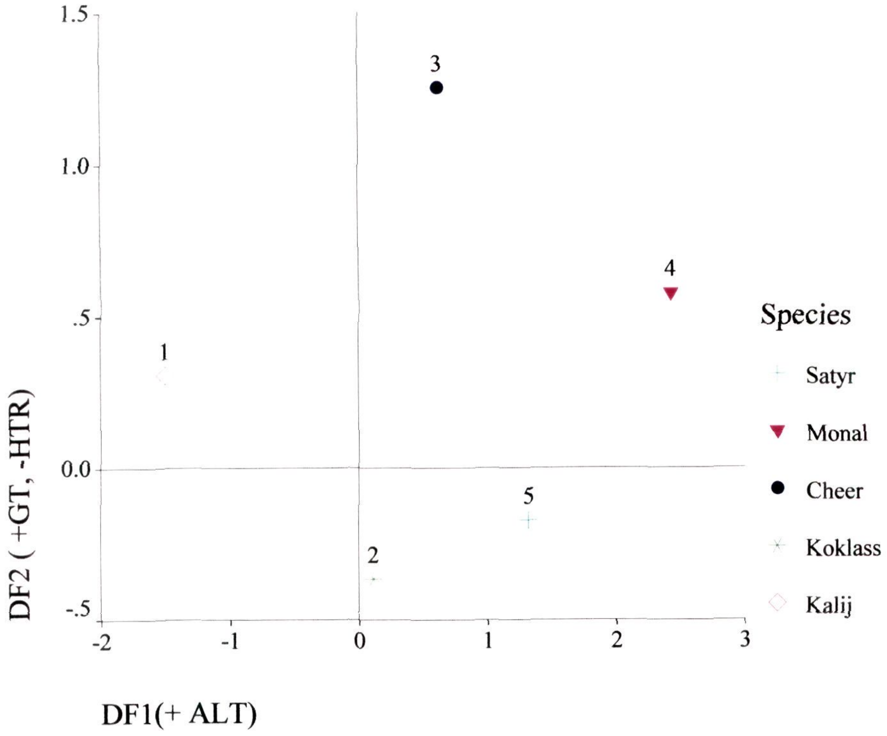


Fig. 5.1 Distribution of Five pheasant species in relation to DF1 and DF2.

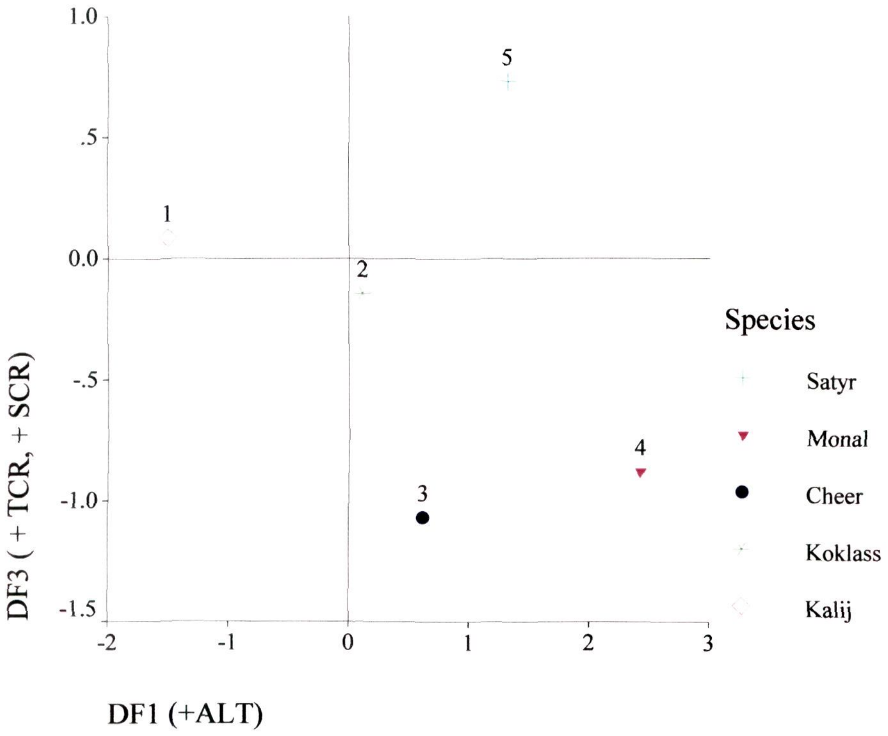


Fig. 5.2 Distribution of Five pheasant species in relation to DF1 and DF3.

with low percentage of grass cover at higher altitude. Monal was found to be separated from the rest by holding areas having medium percentage of grass cover and medium herb density at higher altitude. Figure 5.2 is a plot of function 1 and 3 and it separated Monal and Cheer pheasant from Kalij, Koklass and Satyr by possessing the open areas in terms of lower percentages in tree and shrub cover. Figure 5.3 is a plot of function 2 and 3 and it separated Satyr Tragopan from Monal and Cheer pheasant by preferring close canopy forest with enough under storey with low grass cover and herb density while Kalij and Koklass occupied intermediate place (Fig. 5.3). A three dimensional view of all the three function (Fig. 5.4) separated all the five pheasant species in their respective niche space. The Kalij was distributed in areas low in herb density and low percentages of shrub & grass cover in the close canopy forest at lower altitude. The Koklass was found at the places having more herb density and low percentage of grass cover having enough tree and shrub cover (>40%) at middle altitude while Satyr Tragopan preferred forest areas with close canopy spread and having maximum percentage of shrub cover at higher altitude. Cheer was distributed in the open grassy areas with low abundance of herbs at middle altitude. Monal was found in the open areas with no shrubs but enough in herb density and lower percentage of grass cover at higher altitude.

5.3.2 Binsar Wildlife Sanctuary

5.3.2.1 *Macro habitat use of Kalij and Koklass in BWS*

To observe the difference in the groups of Kalij and Koklass encountered, chi-square test was performed in oak & oak-pine habitats within and between premonsoon 1996 and postmonsoon season 1997. Encounters of Kalij and Koklass on trails 1 & 4

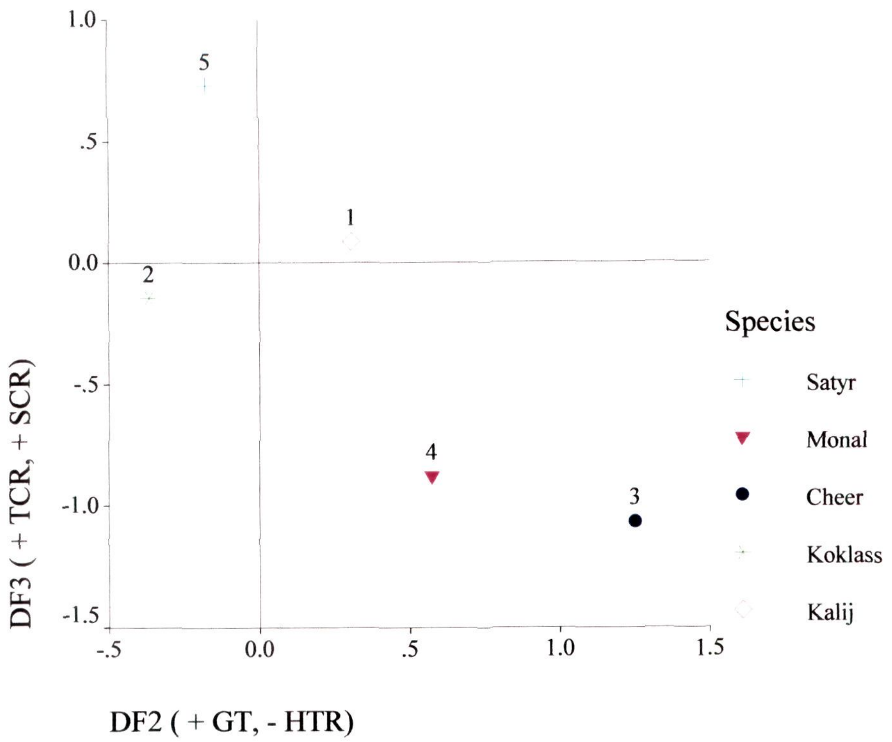


Fig. 5.3 Distribution of Five pheasant species in relation to DF2 and DF3.

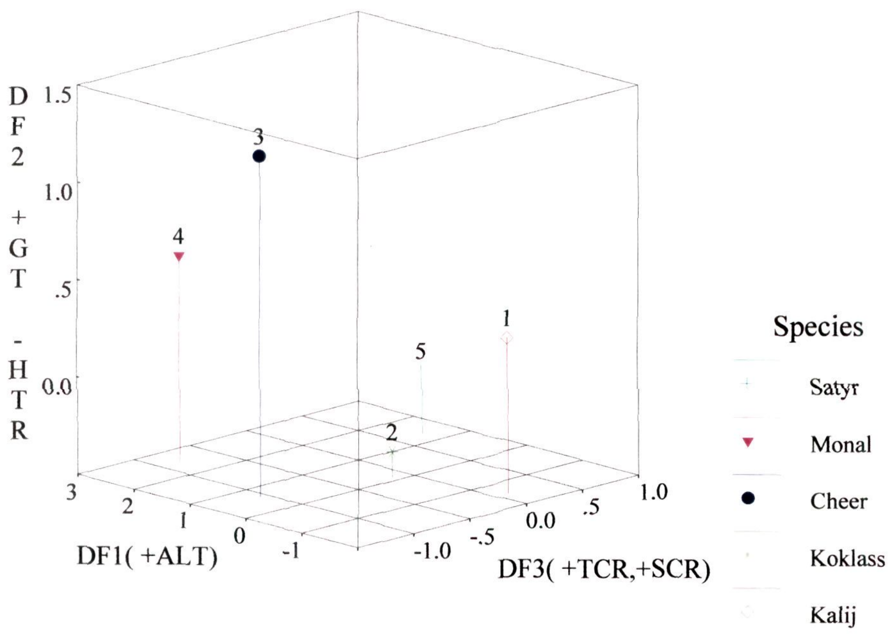


Fig. 5.4 Distribution of Five pheasant species in three dimensional space.

were merged as both of these trails represented oak habitat while trails 2 & 3 possessed oak-pine habitat (Tables 5.5 & 5.6). Chi-square test showed significant difference in Kalij groups encountered in both habitats during premonsoon season ($\chi^2 = 6$, $p < 0.05$) while it was not significant for postmonsoon season. While Koklass showed significant difference in oak and oak-pine habitats during postmonsoon season ($\chi^2 = 8.06$, $p < 0.01$). The test could not be performed for premonsoon season for Koklass. By pooling data for both the habitats, Kalij showed significant difference between premonsoon and postmonsoon seasons ($\chi^2 = 6.0$, $p < 0.05$). Groups of Kalij were encountered more during premonsoon than postmonsoon (Table 5.4). Significant difference was also observed for Koklass groups encountered between the seasons ($\chi^2 = 12.26$, $p < 0.001$).

5.3.2.2 *Habitat preference of Kalij and Koklass in BWS*

Chi-square contingency test was performed for groups of Kalij and Koklass encountered during premonsoon and postmonsoon seasons in oak and oak-pine habitats (Table 5.5). This test showed significant differences in both the variables for Kalij ($\Sigma\chi^2 = 5.72$, $p < 0.05$). The analysis showed that Kalij preferred more oak habitat than expected during premonsoon season. Significant difference was also observed for Koklass ($\Sigma\chi^2 = 4.12$, $p < 0.05$). The analysis showed that Koklass utilised oak habitat during premonsoon more than expected and less than expected during postmonsoon. By pooling the data for both the seasons (Table 5.6), Kalij did not show significant difference in oak and oak-pine habitats. But significant difference was observed in the groups of Koklass encountered in both the habitats ($\chi^2 = 8.32$, $p < 0.01$). Koklass mainly prefer medium canopy forest that's why they were encountered more in oak-pine habitat.

Table 5.4 Overall encounter rate (groups / 100 man-hours) of Kalij and Koklass in Binsar during 1996-1997 in Binsar.

Season	Time spent (minute)	Kalij group	Koklass group	Kalij encounter rate	Koklass encounter rate
Premonsoon 96	3140	16	6	30.57	11.46
Postmonsoon 97	13902	38	24	11.45	10.35

Table 5.5 Number of monitoring, time spent and number of groups of Kalij and Koklass encountered during premonsoon 96 and postmonsoon 97 on different trails in Binsar.

	Premonsoon				Postmonsoon							
					(MORNING)				(EVENING)			
Tn	Nm	Time spent	Kalij groups	Koklass groups	Nm	Time spent	Kalij groups	Koklass groups	Nm	Time spent	Kalij groups	Koklass groups
1	8	505	6	1	25	1845	5	2	14	1280	2	0
2	6	370	0	0	22	2335	4	6	11	1245	4	1
3	7	650	0	0	19	2180	2	5	11	1310	0	1
4	5	270	0	0	27	1230	1	0	8	395	0	0

Tn, = Trail number, Nm = Number of monitoring

Table 5.6 Encounter rate (groups/100 man-hours) of Kalij and Koklass during Premonsoon 96 and Postmonsoon 97 on different trails in Binsar.

		Trail Number				Overall
Season	**Species**	**1**	**2**	**3**	**4**	**encounter ate**
Pre 96	Kalij	71.34	0	0	0	20.06
	Koklass	11.89	0	0	0	33.34
Post 97	Kalij	13.44	10.05	3.43	3.69	8.12
	Koklass	3.84	11.73	10.31	0	7.61

5.3.3 Pindari Reserve Forest

5.3.3.1 *Macro habitat use of different pheasant species*

Overall three habitats were identified, out of four trails used for monitorings. Observations of trail 3 and 4 were merged, which represented mixed habitat. Trails 1 and 2 were in oak and oak-coniferous habitats respectively (Table 5.7). Chi-square test was performed between and within the habitats for premonsoon and postmonsoon seasons of 1998 for different pheasant species. During premonsoon, Koklass ($\chi^2 = 8.27$, $p < 0.02$) and Monal ($\chi^2 = 26.38$, $p < 0.001$) groups encountered showed significant difference in different habitat types. Koklass groups were encountered more in mixed habitat while groups of Monal were encountered maximum in oak-coniferous habitat. Satyr did not show any significant difference between different habitat types during premonsoon while during postmonsoon significant difference were observed ($\chi^2 = 10.5$, $p < 0.01$). The occurrence of Koklass and Monal groups differed significantly between habitats ($\chi^2 = 23.57$, $p < 0.001$; $\chi^2 = 18.0$ $p < 0.001$) during postmonsoon season. Koklass was seen more in mixed habitat while Monal was encountered more in oak-coniferous habitat during postmonsoon season also (Table 5.8).

Irrespective of habitats, when test was performed between seasons, then, only Koklass showed significant difference in number of groups seen during premonsoon and postmonsoon seasons ($\chi^2 = 5.04$, $p < 0.05$) while Kalij, Monal and Satyr did not (Table 5.9). Koklass were encountered more during premonsoon than the postmonsoon, which might be due to the reason that summer is the breeding season (Ali & Ripley, 1987) and

Table 5.8 Mean encounter rate (groups/monitoring) of different pheasant species during premonsoon 98 and postmonsoon 98 on different trails in Pindari.

Season	Species	Trail Number 1	2	3	4	Overall encounter rate
Pre 98	Kalij	0.1 ± 0.31	0	0	0	0.03 ± 0.17
	Koklass	1.4 ± 1.07	1.1 ± 1.19	4 ± 2	0	0.74 ± 1.67
	Monal	0	1.5 ± 2.17	0	0.33 ± 0.57	0.51 ± 1.38
	Satyr	0	0.4 ± 0.51	0.5 ± 0.75	0	0.25 ± 0.51
Post 98	Kalij	0.8 ± 0.28	0	0	0.3 ± 0.48	0.1 ± 0.51
	Koklass	0.2 ± 0.42	1.1 ± 0.56	2 ± 1.05	0.5 ± 0.52	0.92 ± 0.97
	Monal	0	0.9 ± 1.1	0	0	0.22 ± 0.65
	Satyr	0	0.4 ± 1.26	0	0	0.1 ± 0.63

Table 5.8 Mean encounter rate (groups/monitoring) of different pheasant species during premonsoon 98 and postmonsoon 98 on different trails in Pindari.

		Trail Number				
Season	**Species**	**1**	**2**	**3**	**4**	**Overall encounter rate**
Pre 98	Kalij	0.1 ± 0.31	0	0	0	0.03 ± 0.17
	Koklass	1.4 ± 1.07	1.1 ± 1.19	4 ± 2	0	0.74 ± 1.67
	Monal	0	1.5 ± 2.17	0	0.33 ± 0.57	0.51 ± 1.38
	Satyr	0	0.4 ± 0.51	0.5 ± 0.75	0	0.25 ± 0.51
Post 98	Kalij	0.8 ± 0.28	0	0	0.3 ± 0.48	0.1 ± 0.51
	Koklass	0.2 ± 0.42	1.1 ± 0.56	2 ± 1.05	0.5 ± 0.52	0.92 ± 0.97
	Monal	0	0.9 ± 1.1	0	0	0.22 ± 0.65
	Satyr	0	0.4 ± 1.26	0	0	0.1 ± 0.63

Table 5.9 Overall encounter rate (groups / 100 man-hours) of different pheasant species during 1998 in Pindari.

Season	Species	Total groups	Encounter rate	Time spent (minute)
Premonsoon	Kalij	19	14.18	8035
	Koklass	59	45.05	
	Monal	29	21.65	
	Satyr	9	6.72	
Postmonsoon	Kalij	4	4.52	5305
	Koklass	37	41.85	
	Monal	9	10.17	
	Satyr	4	4.52	

they form more groups though the number of individuals might be the same for both the seasons.

5.3.3.2 *Habitat preference of different pheasant species*

To observe the difference in groups of pheasant species encountered in both the seasons in different habitat types, chi-square contingency test was performed. Significant difference was observed for Koklass ($\Sigma\chi^2 = 12.09$, $p < 0.001$) only. Koklass preferred oak habitat more than expected during premonsoon while during postmonsoon they did not. When groups encountered in both the seasons in different habitat types were subjected to statistical test, significant difference was observed in the groups of Koklass ($\Sigma\chi^2 = 22.75$, $p < 0.001$), Monal ($\Sigma\chi^2 = 44.25$, $p < 0.001$) and Satyr ($\Sigma\chi^2 = 9.00$, $p < 0.02$) except Kalij in different habitat types (Table 5.10).

5.3.4 Seasonal variation in micro habitat use of different pheasant species

As already described in the methodology section that habitat preference for all species in different seasons at both sites was examined by Principal component analysis (PCA) followed by logistic regression. PCA extracted main governing environmental factors for each species, which are explained accordingly. Models were constructed using VARIMAX (variance maximum) rotation, by which variance is distributed equally on all the factors by taking the magnitude of factors in consideration. Logistic regression was used on habitat plots and random plots of species. The parameters of the model were estimated using the maximum likelihood method. That is, the coefficients that made observed results most "likely" were selected. Results of different species for premonsoon

Table 5.10 Encounter rate (groups / 100 man-hours) of different species during premonsoon 98 and postmonsoon 98 on different trails in Pindari.

		Trail Number				
Season	**Species**	**1**	**2**	**3**	**4**	**Overall encounter rate**
Premonsoon	Kalij	3.76	0	0	0	0.96
	Koklass	52.23	26.4	103.27	0	52.13
	Monal	0	36	0	13.79	15.44
	Satyr	0	9.6	14.24	0	7.72
Postmonsoon	Kalij	7.45	0	0	16.07	4.52
	Koklass	7.45	30.84	96.8	26.79	41.85
	Monal	0	25.23	0	0	10.17
	Satyr	0	11.21	0	0	4.52

and postmonsoon for both sites are described below. As first three components describe more variance, so only these components were considered for all species for both seasons.

5.3.4.1 *Binsar Wildlife Sanctuary*

a) Kalij: PCA extracted seven factors (eigen value > 1.0), which accounted for 76.99% of variance for premonsoon season. The first three factors explained 51.49% of the total variance in the habitat variables (Table 5.11). The first component had high positive scores of altitude, tree cover, tree density, tree diversity, tree richness, shrub diversity and shrub richness and negative scores of rock, grass cover. This habitat was described as a high altitude, close canopy, mature forest with low rocky area having less grass cover. PC II was highly positively correlated with grass density, grass diversity, grass richness and herb diversity, herb richness and negatively correlated with tree richness hence PC II represented open forest having very high ground cover (herbs and grasses) and PC III was related with low altitude, open canopy forest with high ground cover. The logistic regression had an efficacy of 94.67% correct classification of random and bird plots based on PC I, PC II & PC III. Fig. 5.5 showed that Kalij used more tree cover and high tree density areas during premonsoon season. The factor scores were also tested using Mann-Whitney U test to see whether there was any difference in the use of available habitat and Kalij observed plots. The first three components showed significant difference in the use of random and bird plots (PC I $U = 250$, $p < 0.004$; PC II $U = 214$, $p < 0.001$; PC III $U = 278$, $p < 0.01$).

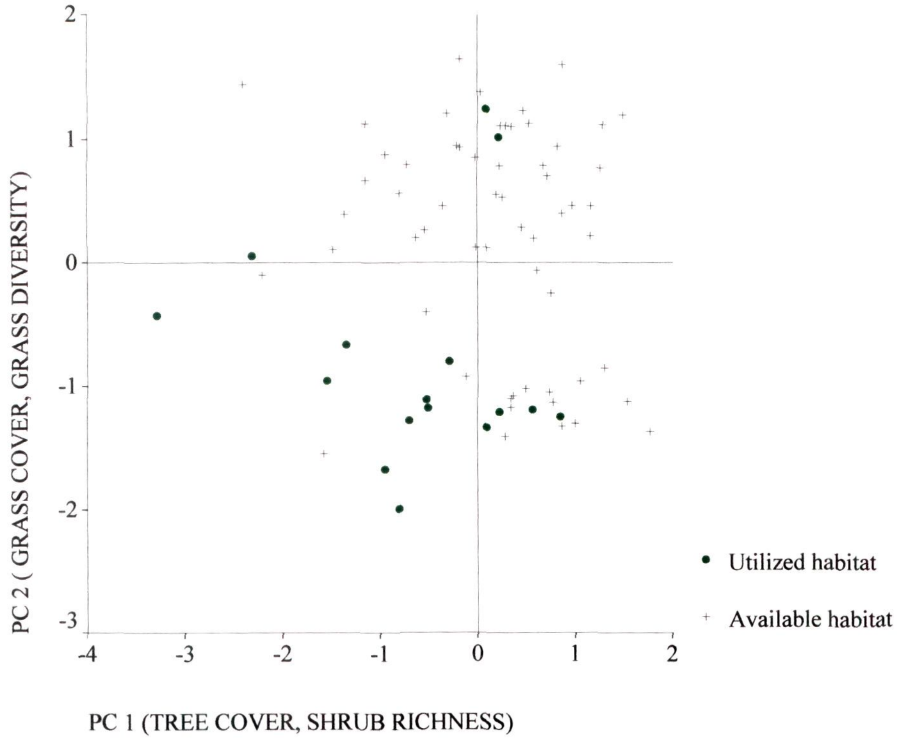


Fig. 5.5 Ordination of available and utilized plots by Kalij during summer 96 in BWS.

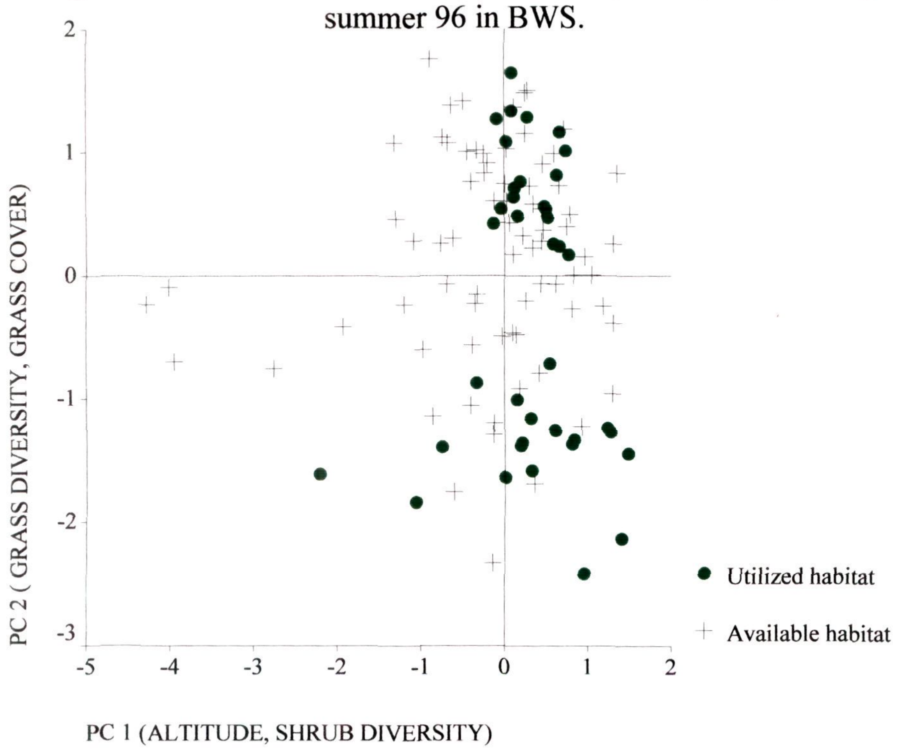


Fig. 5.6 Ordination of available and utilized plots by Kalij during winter 97 in BWS.

Table 5.11 Factor loadings on the PCA components for Kalij during premonsoon 1996.

Variables		PC I	PC II	PC III
	% Variance	26.59	13.88	11.01
	Total variance	76.99%		
Altitude		0.302	-0.005	-0.258
% Bare ground		-0.019	0.219	0.059
Grass diversity		-0.075	0.943	0.261
Grass richness		-0.037	0.935	0.192
Grass density		-0.186	0.825	0.330
Herb diversity		-0.127	0.237	0.925
Herb richness		-0.082	0.245	0.904
% Herb cover		-0.114	-0.090	-0.036
Herb density		-0.130	0.382	0.740
% Rock		-0.230	0.134	0.188
Shrub diversity		0.662	0.027	0.006
Slope		0.141	-0.020	0.139
Shrub richness		0.827	-0.066	-0.022
Shrub density		0.105	0.072	0.016
Tree cover		0.761	-0.084	-0.270
Tree diversity		0.910	-0.091	-0.081
Tree richness		0.739	-0.290	-0.051
Tree density		0.570	0.112	-0.360
% Grass cover		-0.237	0.067	0.177
% Litter		0.153	-0.042	-0.092
% Withered stone		0.162	0.039	0.037
Eigen values		5.58	2.91	2.31

During postmonsoon season, PCA again extracted seven factors (72.32% variance). First three factors accounted for 47.22% of the total variance (Table 5.12). PC I described the close canopy, high tree density, more shrub cover and shrub richness and also more bare ground with less grass cover and grass density habitat while PC II explained more ground cover and low tree cover and less withered stone area. PC III was having close canopy dense forest with low percentage of herb cover. Fig. 5.6 displayed that Kalij was distributed towards high on PC I i.e. high tree density, tree cover, shrub density and shrub cover. Logistic regression analysis correctly classified 85.96% random and bird plots based on PC I, PC II & PC III. U-test also showed significant difference in the available and observed plots by using PC I ($U = 1017$, $p < 0.008$) and PC III ($U = 962$, $p < 0.003$). Kalij used same habitat (close canopy, mature forest) during premonsoon and postmonsoon seasons in Binsar Wildlife Sanctuary.

b) Koklass: Total eight components were extracted by PCA, which explained 82.66% of the total variance during premonsoon season for Koklass. First three components were taken into account as they had high eigen values compared to the rest five and they accounted for 52.02% of the total variance (Table 5.13). The first factor was highly positively correlated with altitude, tree cover, tree diversity, shrub diversity and shrub richness and negatively correlated with grass density and rock cover. This represented a high altitude, more tree cover and shrub cover area with low grass density. Second factor was associated with high grass density, diversity, grass richness and herb density with low tree richness. Third factor again described more ground cover with less canopy cover habitat. When random and bird plots were plotted against first two factors, it indicated

Table 5.12 Factor loadings on the PCA components for Kalij during premonsoon 97.

Variables		PC I	PC II	PC III
	% Variance	23.43	13.84	9.94
	Total Variance	72.33%		
Altitude		0.187	-0.087	0.144
% Bare ground		0.495	-0.095	-0.178
Grass diversity		0.005	0.880	-0.004
Grass richness		0.091	0.820	-0.014
Grass density		-0.320	0.686	0.063
Herb diversity		0.006	0.175	-0.048
Herb richness		0.138	0.174	-0.059
% Herb cover		0.107	0.172	0.112
Herb density		-0.168	0.281	-0.211
% Rock		0.051	-0.022	0.016
Shrub diversity		0.853	-0.010	0.176
Slope		-0.032	-0.150	-0.020
Shrub richness		0.813	-0.057	0.158
Shrub density		0.758	0.009	0.065
Tree cover		0.234	-0.275	0.329
Tree diversity		0.152	0.035	0.951
Tree richness		0.112	-0.025	0.946
Tree density		0.225	-0.011	0.321
% Grass cover		-0.476	0.425	-0.167
% Litter		0.056	-0.227	0.084
% Withered stone		0.246	-0.264	0.010
Eigen values		4.92	2.90	2.08

Table 5.13 Factor loadings on the PCA components for Koklass during premonsoon 1996.

Variables		PC I	PC II	PC III
	% Variance	28.76	11.99	11.25
	Total variance	82.66%		
Altitude		0.719	-0.029	-0.142
% Bare ground		-0.009	0.168	0.149
Grass diversity		-0.105	0.941	0.238
Grass richness		0.007	0.936	0.142
Grass density		-0.356	0.810	0.296
Herb diversity		-0.075	0.172	0.946
Herb richness		-0.053	0.180	0.917
% Herb cover		-0.232	-0.129	-0.079
Herb density		-0.204	0.266	0.749
% Rock		-0.345	0.128	0.123
Shrub diversity		0.872	-0.160	-0.127
Slope		0.180	-0.079	0.114
Shrub richness		0.803	-0.139	-0.066
Shrub density		-0.068	-0.076	-0.049
Tree cover		0.477	-0.212	-0.325
Tree diversity		0.332	-0.153	-0.132
Tree richness		0.233	-0.292	-0.023
Tree density		0.216	0.104	-0.167
% Grass cover		0.217	0.063	0.095
% Litter		0.204	0.005	-0.096
% Withered stone		0.025	-0.007	0.015
Eigen values		6.04	2.52	2.36

that Koklass distribution was more towards PC II whereas the random plots were evenly distributed on PC I (Fig. 5.7). 98.46% correct classification was based on PC II. U-test also revealed the significant difference in random and bird plots on the basis of PC II ($U = 58$, $p < 0.005$). During premonsoon, Koklass used open canopy oak forest with maximum ground cover.

Seven factors were extracted by PCA (71.90% variance) for Koklass for premonsoon season. First three factors accounted for 44.97% of variance (Table 5.14). PC I described the mature forest of high tree density and shrub density, shrub diversity and shrub richness with high litter cover and low grass cover. PC II had high positive loadings of grass density, grass diversity, grass richness and grass cover while negative loadings of tree cover and litter. PC III depicted the forest of high tree density and tree diversity with low herb cover on gentle slope. Logistic regression classified 83.84% of plots correctly on the basis of PC III. Since PC I & PC II had high variance loadings so the graph was plotted for random and bird plots against these two factors (Fig. 5.8). Graph revealed that observed plots were distributed more towards high tree cover and litter cover with low grass cover. U-test was performed to see whether there was any significant difference in the use of habitat variables in the random (available) and Koklass observed plots (utilized). There was significant difference in available and utilised habitats by Koklass on the basis of PC III ($U = 576$, $p < 0.008$). There was difference in habitat use of Koklass between premonsoon and postmonsoon seasons. During premonsoon, it preferred more open canopy cover and high ground cover areas while in postmonsoon it preferred high tree density and low ground cover areas though it showed less variance.

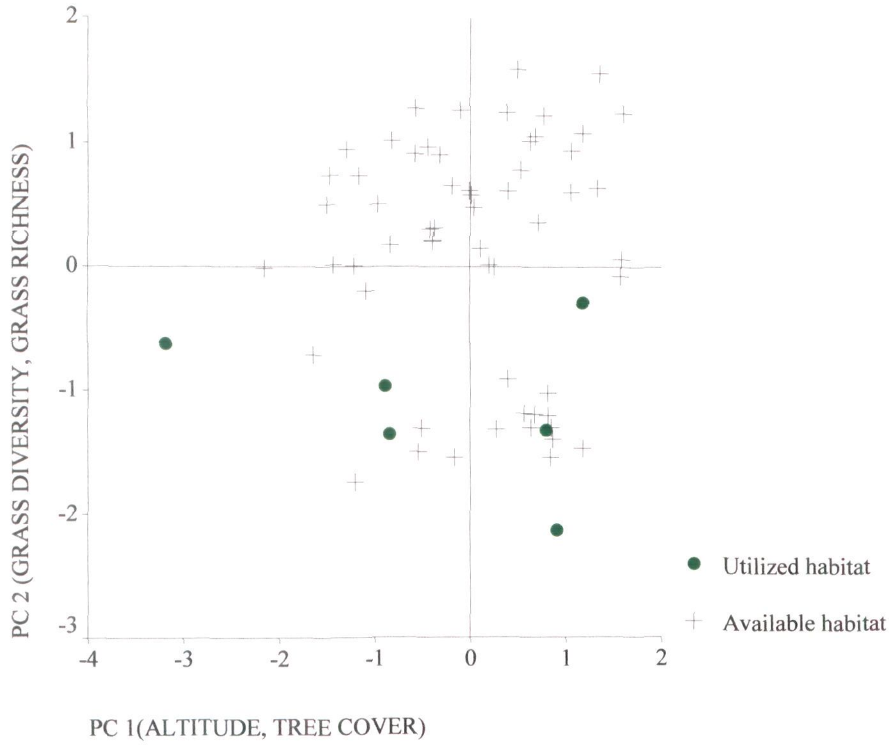


Fig. 5.7 Ordination of available and utilized plots by Koklass during summer 96 in BWS.

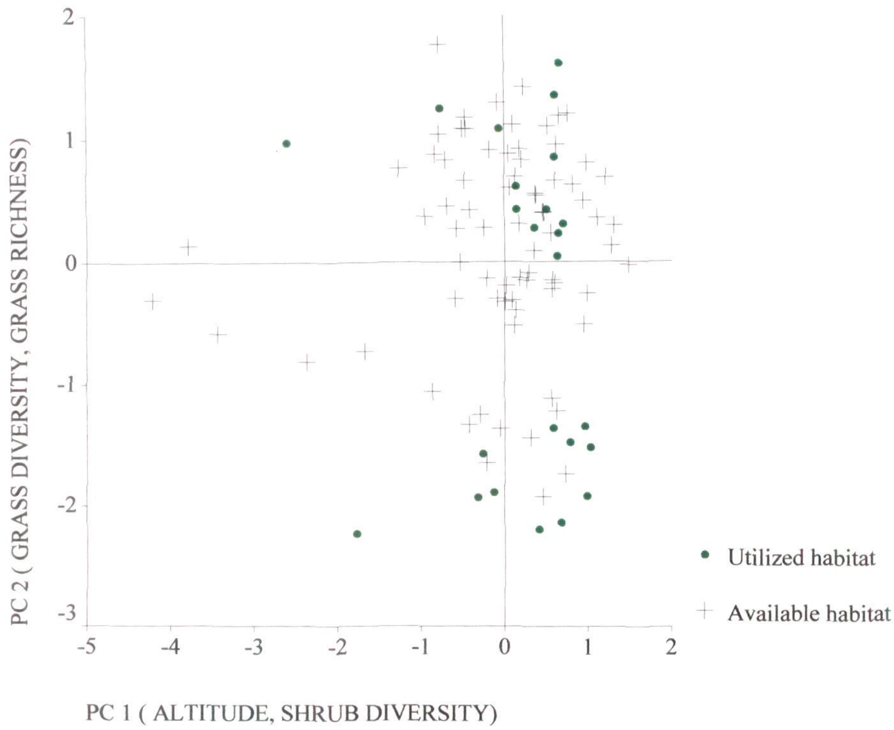


Fig. 5.8 Ordination of available and utilized plots by Koklass during winter 97 in BWS.

Table 5.14 Factor loadings on the PCA components for Koklass during postmonsoon 97.

Variables		PC I	PC II	PC III
	% Variance	23.80	10.95	10.21
	Total variance	71.91%		
Altitude		0.235	0.125	0.141
% Bare ground		0.220	0.148	-0.0009
Grass diversity		-0.034	0.930	-0.043
Grass richness		-0.015	0.819	-0.049
Grass density		-0.336	0.654	0.049
Herb diversity		-0.023	0.104	-0.045
Herb richness		-0.034	-0.058	-0.051
% Herb cover		0.163	0.022	-0.031
Herb density		0.073	0.178	-0.306
% Rock		0.123	0.174	-0.019
Shrub diversity		0.868	-0.038	0.127
Slope		-0.135	-0.124	-0.234
Shrub richness		0.828	-0.062	0.145
Shrub density		0.751	-0.050	0.069
Tree cover		0.326	-0.299	0.325
Tree diversity		0.155	0.027	0.951
Tree richness		0.121	-0.075	0.944
Tree density		0.251	-0.025	0.463
% Grass cover		-0.621	0.321	-0.138
% Litter		0.267	-0.355	0.0531
% Withered stone		0.006	0.065	-0.024
Eigen values		4.99	2.30	2.14

5.3.4.2 *Pindari Reserve Forest*

a) Kalij: Overall nine factors were extracted by PCA, which accounted for 82.44% of variance for premonsoon season for Kalij. First three factors were taken into consideration, which together explained 45.18% variance in data matrix (Table 5.15).

The first factor had positive correlation with tree diversity and richness, shrub density and richness and negative correlation with altitude, bare ground, grass diversity and slope. This factor described mature forest on low altitude and gentle slope with low grass diversity. Second factor reflected the forest with high ground cover and low shrub cover on high altitude and third factor summarized as low altitude, high shrub cover area with high tree richness on steeper slope. Fig. 5.9 showed that Kalij was distributed in the low altitude area with high tree and shrub density. The logistic regression had an efficacy of 91.73% correct classification of random and bird plots based on the PC I & PC II. U-test indicated that PC I ($U = 854$, $p < 0.02$) and PC II ($U = 538$, $p < 0.00$) were significant suggesting that there was significant difference in the use of habitat variables in the random and Kalij observed plots. During premonsoon season, Kalij used low altitude area with high shrub and tree diversity. The test could not be possible for postmonsoon season.

b) Koklass: Six factors were extracted by PCA (70.05% of variance) (Table 5.16) for premonsoon season for Koklass. First factor had high positive loadings of grass diversity, richness and density, herb diversity, richness and density and grass cover. This depicted a high ground cover forest area. Second factor was highly positively correlated with herb diversity, richness, density and shrub density and negatively correlated with slope and

Table 5.15 Factor loadings on the PCA components for Kalij during premonsoon 98.

Variables		PC I	PC II	PC III
	% Variance	18.66	15.32	11.19
	Total variance	82.44%		
Altitude		-0.746	0.173	-0.218
% Bare ground		-0.365	0.047	-0.022
Grass diversity		-0.212	0.869	0.025
Grass richness		-0.039	0.849	0.092
Grass density		-0.034	0.740	-0.075
Herb diversity		0.064	0.194	0.065
Herb richness		0.137	0.152	0.143
% Herb cover		-0.157	-0.034	0.076
Herb density		-0.100	0.110	-0.023
% Rock		0.136	-0.202	0.057
Shrub diversity		0.115	0.064	0.926
Slope		-0.194	0.152	0.226
Shrub richness		0.172	0.089	0.898
Shrub density		0.256	-0.178	0.622
Tree cover		0.092	-0.091	0.064
Tree diversity		0.892	-0.046	0.115
Tree richness		0.892	-0.064	0.179
Tree density		0.093	0.117	0.015
% Grass cover		0.137	0.503	0.014
% Litter		0.158	-0.115	0.018
% Withered stone		0.208	0.049	-0.016
Eigen values		3.92	3.21	2.35

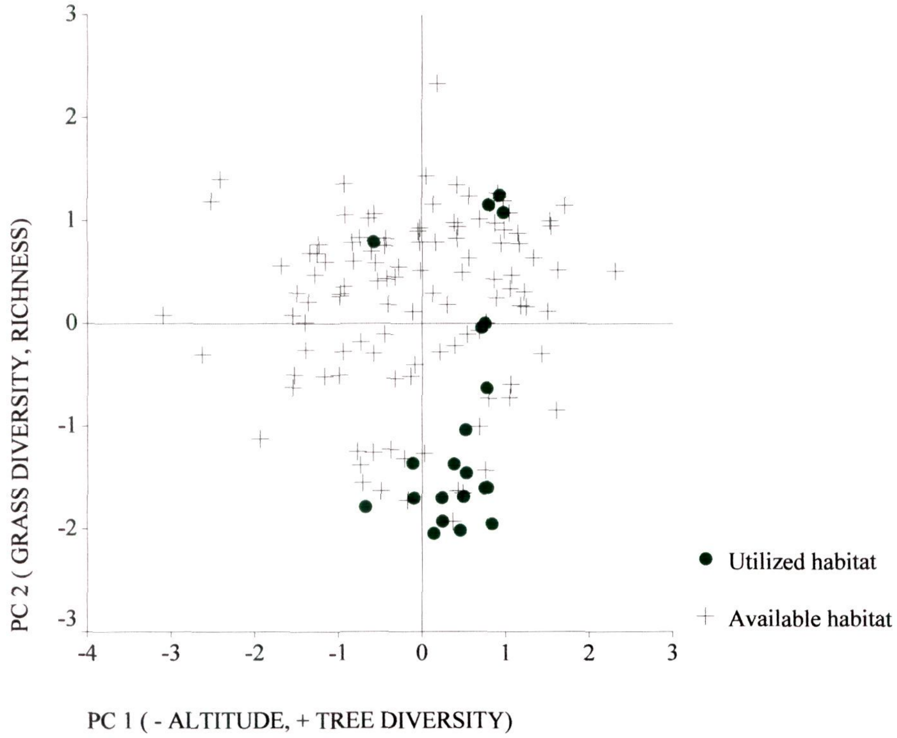


Fig. 5.9 Ordination of available and utilized plots by Kalij during summer 98 in Pindari.

tree cover, representing high ground and shrub area on gentle slope. Third factor represented low altitude area with high tree diversity and richness. Figure 5.10 showed that Koklass were distributed towards low ground cover but high herb cover whereas all plots were distributed on negative side of PC I. Logistic regression had an efficiency of 84.36% correct classification of random and Koklass observed plots on the basis of PC I & PC II. Mann- Whitney U test was used on these factors to see whether there was any difference in the use of random plots (availability) and Koklass observed plots (utilisation). PC I was significant suggesting that there was significant difference in the use of habitat variables in the random and bird observed plots ($U = 967$, $p < 0.001$).

First three factors explained 43.92% of the total variance for postmonsoon season (Table 5.17). First component described high herb cover, herb density, grass density, cover and low tree cover, density and litter. Second factor summarized high herb and grass density, diversity and low shrub richness and rock cover. Third factor represented forest areas at lower altitude having high tree diversity and richness. It was clarified from Fig. 5.11 that all observed plots were mainly distributed on PC II i.e. high grass and herb cover and low shrub richness and rock cover. Regression analysis correctly classified 94.80% of random and bird plots on the basis of PC I & PC II. U-test also revealed significant difference in the use of habitat variables in the random and bird observed plots on the basis of PC I ($U = 2265$, $p < 0.01$) and PC II ($U = 592$, $p < 0.00$). During premonsoon, Koklass preferred low ground cover where as during postmonsoon it preferred high grass and cover areas.

Table 5.16 Factor loadings on the PCA components for Koklass during premonsoon 98.

Variables		PC I	PC II	PC III
	% Variance	19.82	15.85	11.43
	Total variance	70.05%		
Altitude		0.008	-0.136	-0.756
% Bare ground		0.629	0.081	-0.207
Grass diversity		0.879	0.105	-0.040
Grass richness		0.856	0.076	0.081
Grass density		0.777	0.132	0.011
Herb diversity		0.361	0.758	0.141
Herb richness		0.348	0.660	0.210
% Herb cover		-0.288	0.735	-0.184
Herb density		0.202	0.767	-0.097
% Rock		-0.118	-0.421	0.250
Shrub diversity		0.090	0.017	0.128
Slope		0.093	-0.484	0.018
Shrub richness		0.093	-0.008	0.180
Shrub density		0.034	0.203	0.136
Tree cover		-0.025	-0.264	0.018
Tree diversity		-0.032	-0.056	0.931
Tree richness		-0.059	-0.072	0.930
Tree density		0.073	-0.000	-0.014
% Grass cover		0.616	-0.021	0.032
% Litter		-0.101	0.026	0.016
% Withered stone		0.008	-0.081	0.125
Eigen values		4.16	3.32	2.40

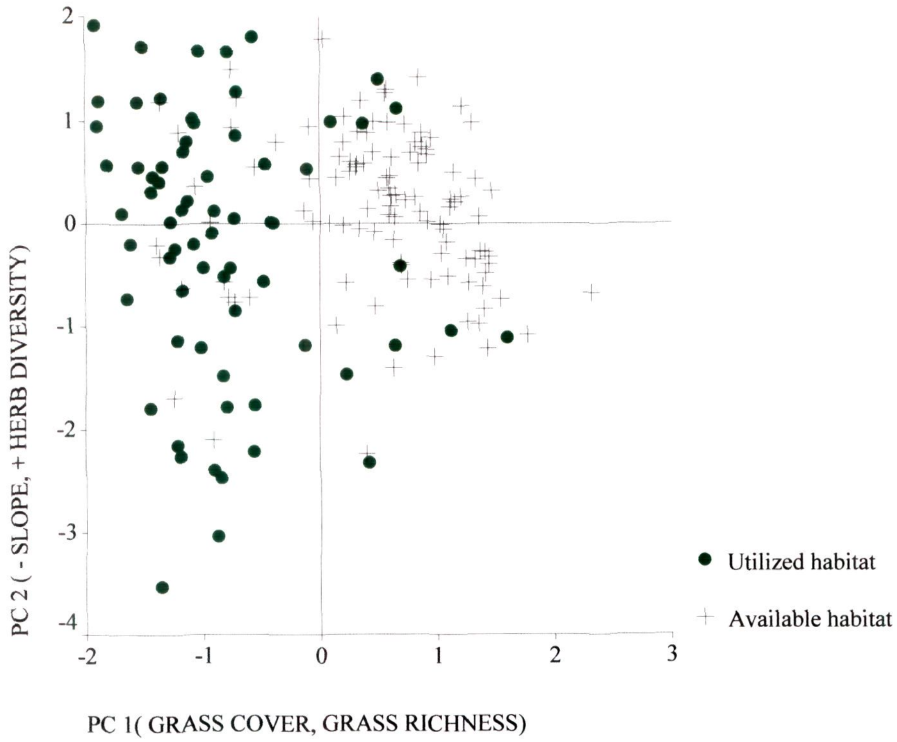


Fig. 5.10 Ordination of available and utilized plots by Koklass during summer 98 in Pindari.

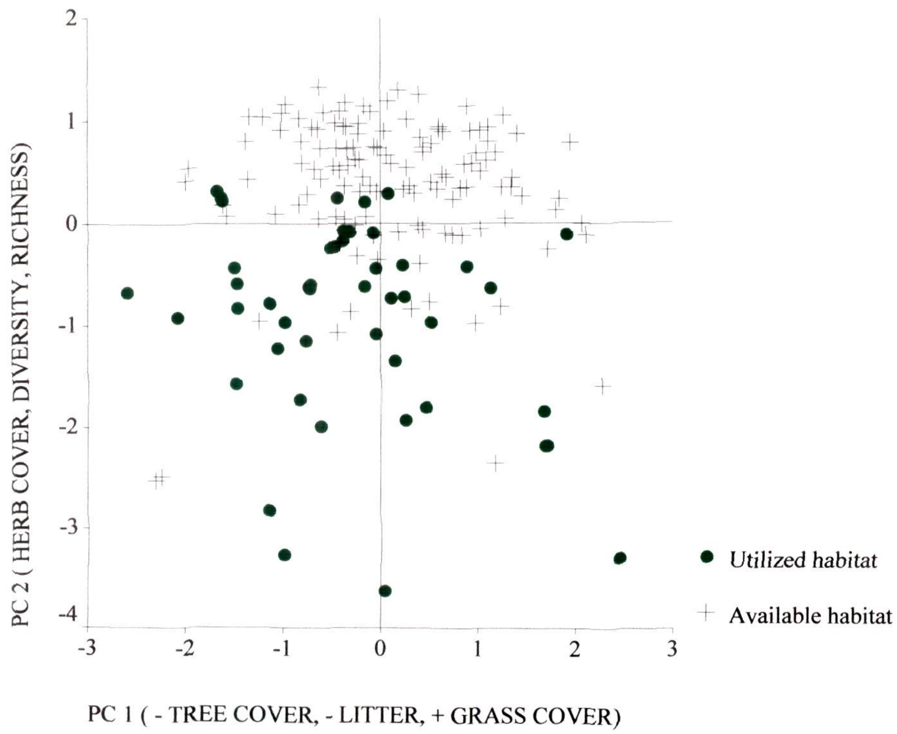


Fig. 5.11 Ordination of available and utilized plots by Koklass during winter 98 in Pindari.

Table 5.17 Factor loadings on the PCA components for Koklass during postmonsoon 98.

Variables		PC I	PC II	PC III
	% Variance	20.00	13.51	10.40
	Total variance	72.22%		
Altitude		-0.020	-0.037	-0.687
% Bare ground		0.052	-0.051	-0.288
Grass diversity		0.187	0.095	-0.059
Grass richness		0.051	0.085	0.021
Grass density		0.638	0.198	-0.134
Herb diversity		0.147	0.923	0.005
Herb richness		0.039	0.951	0.028
% Herb cover		0.614	0.251	0.175
Herb density		0.627	0.623	-0.022
% Rock		-0.152	-0.187	0.021
Shrub diversity		0.064	0.044	0.079
Slope		-0.037	-0.133	-0.029
Shrub richness		-0.149	-0.480	0.055
Shrub density		-0.026	0.158	0.105
Tree cover		-0.544	-0.144	0.052
Tree diversity		-0.071	-0.012	0.936
Tree richness		-0.024	-0.004	0.950
Tree density		-0.380	0.092	-0.074
% Grass cover		0.614	-0.044	-0.081
% Litter		-0.843	-0.051	0.046
% Withered stone		0.169	0.245	0.075
Eigen values		4.20	2.83	2.18

c) Monal: PCA extracted six components, which explained 71.43% of the total variance, and first three components explained 50.68% of variance for Monal for premonsoon season (Table 5.18). First component outlined the forest on low altitude having high tree diversity, richness and density. Second component represented areas with low altitude, high ground cover and dense and rich shrub cover. Third component described high ground cover and low litter. Fig. 5.12 exhibited that bird plots were distributed on the lower sides of both the axes i.e. PC I & PC II. During premonsoon season, Monal preferred high altitude and high ground cover with relatively low tree cover and low tree density areas. Logistic regression correctly classified 92.91% random and Monal observed plots on the basis of PC I, PC II & PC III. U-test showed the significant difference in the random and Monal observed plots on the basis of PC I ($U = 800$, $p < 0.00$), PC II ($U = 794$, $p < 0.00$) and PC III ($U = 938$, $p < 0.00$).

During postmonsoon season, PCA extracted seven components, which accounted for 73.89% of the total variance. First three components explained 45.11% of variance (Table 5.19). PC I summarized the forest areas on low altitude, high ground cover and low shrub cover with gentle slope. PC II showed high positive loading of tree cover, density and litter while negative loading of grass density, herb density and shrub richness. PC III represented areas with high ground cover with low shrub density and litter. Monal used areas with high tree cover and high ground cover during postmonsoon (Fig. 5.13). Random plots and bird observed plots were 100% correctly classified on the basis of PC I & PC II. Mann-Whitney U-test showed significant difference in the use of habitat variables in the Monal observed and random plots on the basis of PC I ($U = 38$, $p < 0.00$) and PC II ($U = 268$, $p < 0.001$).

Table 5.18 Factor loadings on the PCA components for Monal during premonsoon 98.

Variables		PC I	PC II	PC III
	% Variance	25.02	13.62	12.02
	Total variance	71.43%		
Altitude		-0.758	-0.359	-0.184
% Bare ground		-0.193	-0.013	0.161
Grass diversity		-0.029	0.230	0.835
Grass richness		0.078	0.312	0.744
Grass density		0.096	-0.021	0.832
Herb diversity		0.176	0.474	0.203
Herb richness	.	0.230	0.518	0.172
% Herb cover		-0.333	0.138	-0.177
Herb density		0.105	0.344	0.070
% Rock		0.083	0.038	-0.008
Shrub diversity		0.170	0.905	0.081
Slope		-0.175	0.202	-0.029
Shrub richness		0.198	0.882	0.063
Shrub density		0.374	0.516	0.227
Tree cover		0.034	0.060	-0.118
Tree diversity		0.864	0.154	0.048
Tree richness		0.862	0.202	0.032
Tree density		0.262	0.080	0.123
% Grass cover		0.157	-0.070	0.717
% Litter		0.168	0.202	-0.284
% Withered stone		0.525	0.081	-0.048
Eigen values		5.25	2.86	2.52

Table 5.19 Factor loadings on the PCA components for Monal during postmonsoon 98.

Variables		PC I	PC II	PC III
	% Variance	21.79	13.34	9.98
	Total variance	73.89 %		
Altitude		-0.253	-0.054	0.091
% Bare ground		-0.104	0.228	0.365
Grass diversity		0.066	-0.127	0.920
Grass richness		0.073	-0.009	0.944
Grass density		0.202	-0.496	0.500
Herb diversity		0.909	-0.115	0.052
Herb richness		0.874	-0.066	0.074
% Herb cover		0.491	-0.310	0.060
Herb density		0.749	-0.406	0.159
% Rock		0.112	0.048	0.154
Shrub diversity		0.001	-0.033	-0.076
Slope		-0.246	0.391	0.071
Shrub richness		-0.672	-0.285	0.022
Shrub density		0.132	-0.104	-0.171
Tree cover		-0.113	0.821	-0.081
Tree diversity		-0.123	0.107	-0.046
Tree richness		-0.112	-0.044	0.017
Tree density		0.059	0.809	0.054
% Grass cover		0.041	-0.593	0.178
% Litter		-0.319	0.547	-0.353
% Withered stone		0.111	0.024	0.032
Eigen values		4.57	2.80	2.09

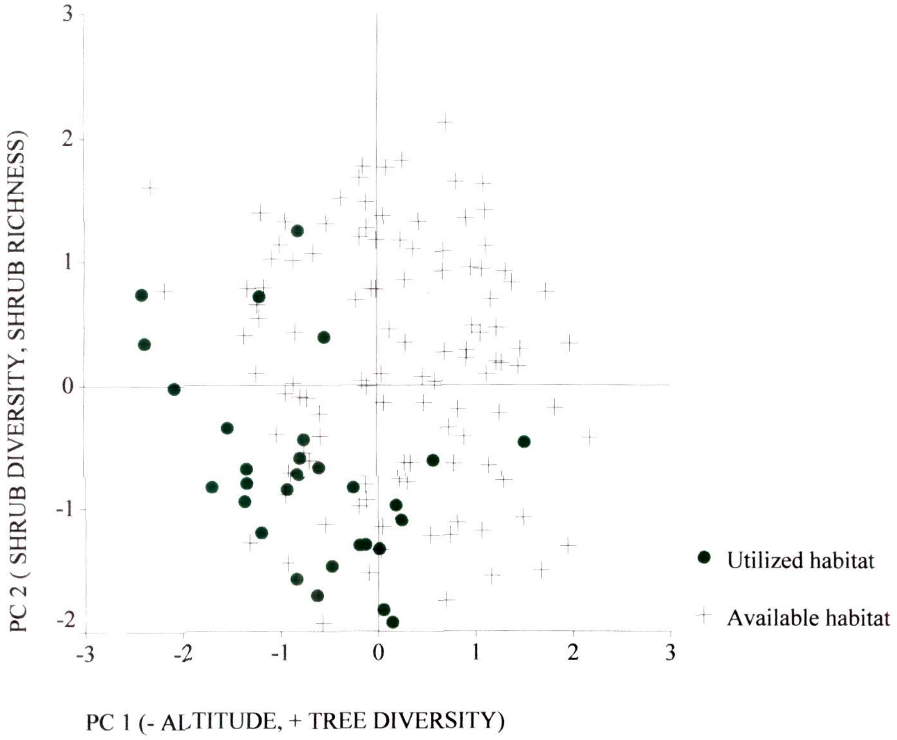


Fig. 5.12 Ordination of available and utilized plots by Monal during summer 98 in Pindari.

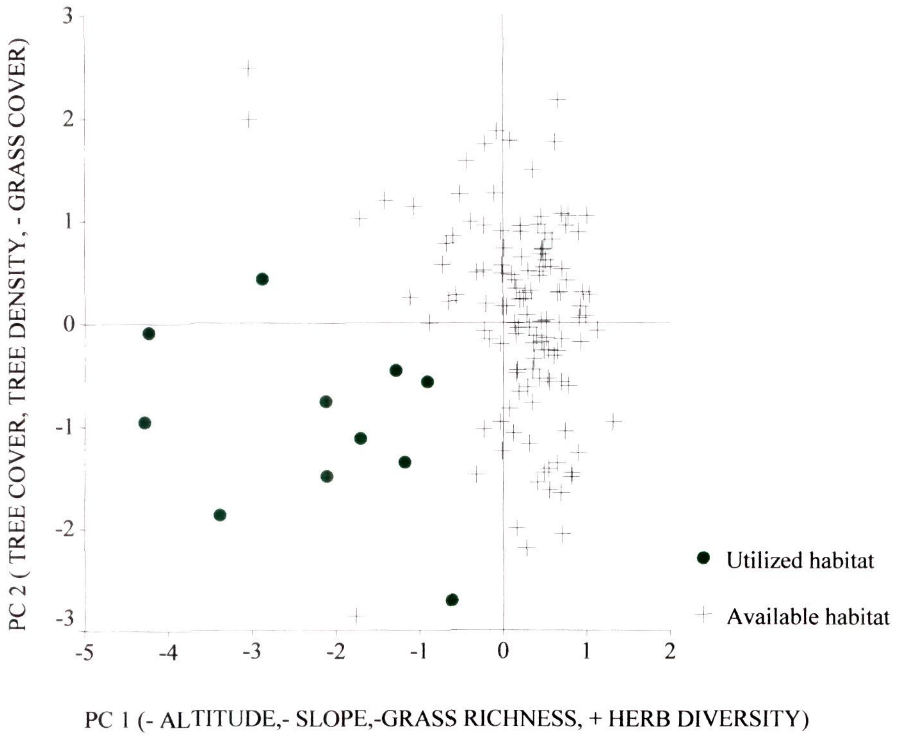


Fig. 5.13 Ordination of available and utilized plots by Monal during winter 98 in Pindari.

d) Satyr Tragopan: PCA extracted seven components (75.27% of variance) in data matrix for Satyr Tragopan for premonsoon season (Table 5.20). The first factor was highly positively correlated with tree diversity, richness, shrub richness, litter and withered stone and negatively correlated with altitude, bare ground and herb cover. It represented low altitude forest with high tree density and litter and low ground cover. Second factor explained the forest with high ground cover with low litter. While third factor represented low altitude, steep slope and high shrub density, shrub cover and shrub richness. Figure 5.14 showed that during premonsoon season Satyr was found more in the areas where ground cover was low and litter was high. Logistic regression correctly classified 94.44% of random and observed plots on the basis of PC II & PC I. U-test revealed significant difference in the use of habitat variables on the basis of PC II ($U = 255$, $p < 0.00$).

During postmonsoon season, PCA extracted eight components, which accounted for 78.58% of variance (Table 5.21). First component described the forest areas with high ground cover and low tree cover, tree density and litter. Second component appeared to be a low altitude with high ground cover and lower shrub rich area. Third component seemed to be a wooded forest with high tree diversity and richness on low altitude. Satyr used low tree cover as well as low shrub richness area with high ground cover (Fig. 5.15). Regression classified 97.08% of random and bird plots correctly on the basis of PC I & PC II. The use of the PC II ($U = 51$, $p < 0.00$) showed significant difference in the use of habitat variables in the random and bird plots.

Table 5.21 Factor loadings on the PCA components for Satyr Tragopan during postmonsoon 98.

Variables		PC I	PC II	PC III
	% Variance	22.38	12.98	10.24
	Total variance	78.58 %		
Altitude		0.039	-0.224	-0.610
% Bare ground		-0.114	-0.039	-0.142
Grass diversity		0.142	0.119	-0.054
Grass richness		0.046	0.130	0.018
Grass density		0.616	0.078	-0.068
Herb diversity		0.180	0.895	-0.077
Herb richness		0.082	0.856	-0.031
% Herb cover		0.507	0.421	0.246
Herb density		0.477	0.733	-0.006
% Rock		-0.019	-0.036	0.042
Shrub diversity		-0.075	0.017	0.190
Slope		-0.383	-0.287	-0.064
Shrub richness		0.222	-0.722	-0.060
Shrub density		0.015	0.076	-0.007
Tree cover		-0.752	-0.237	0.075
Tree diversity		-0.146	-0.055	0.926
Tree richness		-0.006	-0.076	0.941
Tree density		-0.654	-0.025	0.246
% Grass cover		0.721	-0.149	-0.057
% Litter		-0.800	-0.148	-0.043
% Withered stone		-0.022	0.045	0.007
Eigen values		4.70	2.72	2.15

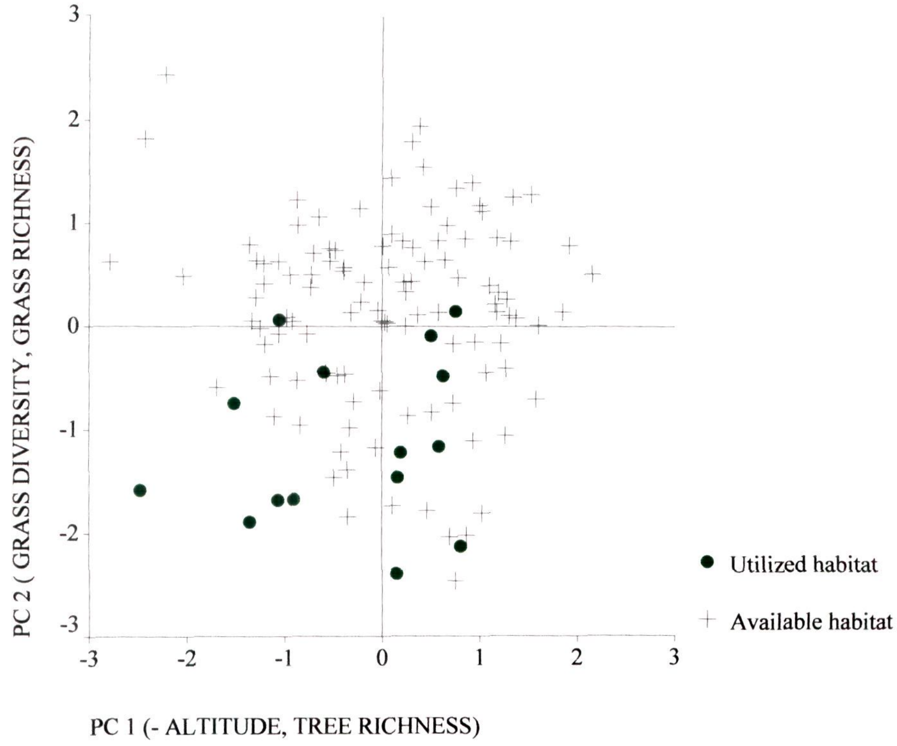


Fig. 5.14 Ordination of available and utilized plots by Satyr during summer 98 in Pindari.

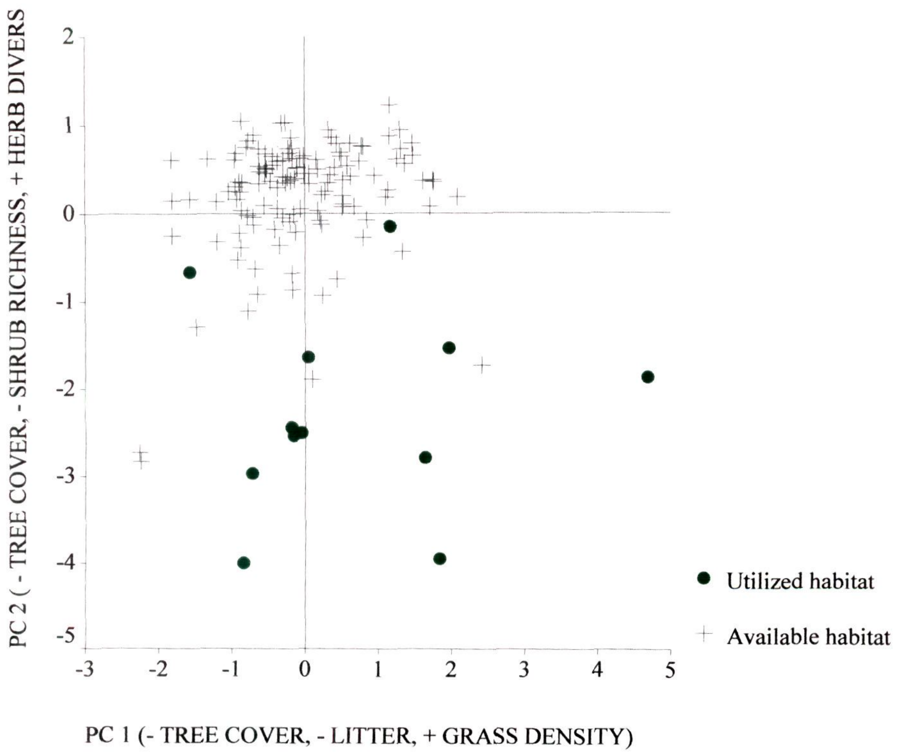


Fig. 5.15 Ordination of available and utilized plots by Satyr during winter 98 in Pindari.

5.4 DISCUSSION

5.4.1 Ecological Separation

Ecologists have long been concerned with explaining pattern of habitat segregation in closely related or ecologically similar animal species (Connell, 1961; Jaeger, 1971; Grant, 1972 and Schoer, 1974). It has been demonstrated, both theoretically and quantitatively in the field, that no two species can occupy the same niche for any prolonged period of time but displace each other in such a manner that each take possession of peculiar type of food and modes of life in which it has an advantage over its competitors (Gause, 1934; Hutchinson, 1959 and MacArthur, 1968; 1970). Habitat separation between similar species may function to reduce interspecific competition (Reinert, 1984). Within the framework of niche theory such differences are linked to the principles of the competitive exclusion concerning the inability of ecological equivalents to coexist stably (Gause, 1934). Partitioning of habitat has been theoretically considered and empirically found to be the most common form of sympatric-species separation (MacArthur & Wilson 1967 and Schoener, 1974). Habitat differences are often cited as being responsible for multispecies coexistence (Schoener, 1974; Cody, 1978 and Duecer & Shugart, 1979).

The current study provided significant ecological separation between population of five pheasant species (Kalij, Koklass, Himalayan Monal, Satyr Tragopan and Cheer pheasant) in Kumaon. Such marked separation between these species could not have been anticipated by comparing general literature accounts of preferred habitats because none of the studies on pheasants together taken into account for ecological studies of these five species.

The results obtained from discriminant function analysis placed Kalij, Koklass, Himalayan Monal, Satyr Tragopan and Cheer pheasant in their respective ecological space. Few habitat factors were found to be mainly responsible for separating these species. Altitude, which determines the vegetation composition at specific area (Mani, 1974), was the key factor that governed the distribution of these species in the specific habitat space. The unique position of each pheasant species in distinct ecological space visualized the concept of niche diversification. It has been observed for those populations of closely related species that succeed in the same area are often found to differ one another in the time at which they make their heaviest demand on the available resources (Pielou, 1974).

Kalij was found to be associated with areas having low percentage of grass cover with enough herb density and sufficient shrub cover in the closed canopy forest at middle altitude (1500-2500m). The middle altitude range is the vertical belt of ecological unit, which constitutes subtropical and tropical mixed deciduous and broad-leaved oak forests. This habitat unit is the exclusive required habitat space for various activities like foraging, breeding and roosting for Kalij (Sharma *et al.* 1993). Besides, the more litter and high decomposition rate of this habitat render humus rich with organic compound and microfauna which may be an additional cause of preference of this ecological unit over others to get more food. In other ecological condition the required vegetation components by Kalij were found to be lacking (Sharma & Chandola, unpublished report). These areas also provide enough scrape materials with more herb abundance and shrub cover required for Kalij nesting (Shafique, 1999). Moreover, these habitats are not utilized by other pheasant species of Kumaon for certain activities during most of the time of the year, which provided less competitive environment for life supporting activities for Kalij.

Koklass pheasant has been generally described as inhabiting mixed hardwood forest with good undergrowth (Wilson & Baldwin in Hume & Marshal, 1879; Beebe, 1926; Baker, 1930 and Ali & Ripley, 1983). In Kumaon, Koklass was found in mixed forests, which were floristically similar to each other in broad features but differed notably in such aspects as species composition and diversity, density, physiognomy, topographic characteristics and extent of disturbance. But habitat factors such as gradient of altitude, amount of grass and proportions of herb cover and tree cover discriminated Koklass significantly from Kalij, Himalayan Monal, Satyr and Cheer pheasant. The unique habitat occupancy of Koklass separated them from rest of the pheasants of Kumaon. The species was seen between the altitude range of 1830-3180m and this range overlapped with altitude ranges of rest of the pheasants. Koklass mostly inhabited areas having very low proportion of grass with abundant herbs at the ground vegetation and enough shrub cover in the partially close canopy forest at middle altitude. The middle altitude region of the Kumaon Himalaya is the most precipitous altitudinal belt (Singh, 1987) and constitutes luxuriant undergrowth at ground level and shrub level. It is reported that Koklass are largely vegetarian and are frequently grazers by habit (Severinghaus, 1990 and Gaston, 1981). The abundant herbs and short shrubs must have provided Koklass seeds, young leaves and shoots as food base. I have personally observed Koklass feeding on *Nerium* sp. (a shrub sp.) and *Pteridium* sp. leaves (a herb). Moreover, these precipitous slopes in rocky areas also provided nesting site for Koklass as has been observed by Roberts (1970) in Pakistan.

Cheer occupied unique ecological space within the distribution range in Kumaon. The species was found in most critical state due to shrinkage of its unique habitat in Kumaon and elsewhere (Kalsi, 2001). The species was associated with areas having higher percentage of grass cover with few herbs in open areas at middle altitude. These areas mainly represented scrub forests with scattered trees, particularly with rocky crags. The species represented the same habitat elsewhere in Kumaon (Kaul, 1989a) and in Himachal Pradesh (Gaston, 1989). Adult Cheer is generally grainivore and herbivore by nature as has been documented by Kaul (1989b). The major portion of Cheer diet was mainly composed of grass leaves, roots and leaves of some herbs. The Cheer inhabiting areas also produced bulk amount of invertebrate fauna as food base for chick for their protein requirement (Kaul, 1989c). It is reported that insect abundance has been related to chick survival rates in the Ring-necked pheasant in UK (Hill, 1985). These areas also provided roosting and nesting sites for Cheer because droppings and feathers were found at the rocky hillsides having long grass beneath the rock jutting which definitely confirmed the species presence for the purpose. The other pheasant species of Kumaon rarely occupied this kind of habitat and it provided less competitive environment for Cheer survival.

The Himalayan Monal occupied higher elevation having enough grass cover with abundant herbs in the open areas. They were found most of the time on the southeastern slopes in sub-alpine areas. It is reported that the species inhabit high altitude oak-conifer (*Quercus-Abies*) forests, Birch-Rhododendron forests, steep and grassy meadow with an altitudinal range from 2600-5000m (Ali & Ripley, 1983 and Gaston *et al.* 1981) in different seasons of the year. This unique ecological condition provided its preferred habitat required for various ecological activities such as Himalayan Monals are reported to choose protected raised ledges on southeastern slopes of steep cliff or outjutting measure of boulders for their roosting (Beebe, 1918-22). The ecological position of Monal has some advantage over other pheasant species in Kumaon. The higher reaches on the mountains are characterised by severe climatic conditions with low human habitation and low anthropogenic pressures. Consequently, these habitat characteristics provide free flowing life supporting activities. Moreover, these areas also restrict predation activities to a great extent with low risk of nest damage and nest predation (egg collection) by human and natural enemies.

The Satyr Tragopan seemed to be rare among all the pheasants in Kumaon in terms of its distribution and abundance (discussed in previous chapters). The preferred habitat represented closed canopy forest having sufficient shrub cover at higher elevation. General habitat occupancy of Satyr in Kumaon agreed with findings of Khaling (1998) in Singhalila National Park, Darjeeling, who documented the species association with habitat variables like tree canopy cover and shrub cover. Cover is important in reflecting the primary forest or edge areas within the forest. Similar to the studies of Islam & Crawford (1987) on the habitat of Western Tragopan, it emerged that in a Satyr habitat the structural components of the vegetation at the shrub and ground level were more important. Tall and dense shrubs are said to be important for Satyr females that were nesting for cover and protection, and also shorter shrubs and ground cover would be important for the brood (Khaling, 1998). The brightly coloured male gets protection from dense cover from potential predators. Being primarily ground dwelling and herbivore, the ground vegetation provide the species abundant and easily procurable food (Khaling, 1998).

5.4.2 Microhabitat Use

Several authors (Lack, 1933 & 1949; Swardson, 1949 and Hilden, 1965) have theorised that birds select habitat on the basis of 'sign stimuli' that convey information about ultimate factors like food production and nest site availability. Root (1967) documented cases in which mentioned, bird species appear to be directly associated with ultimate factors. Other studies have documented the structural and functional components of vegetation usually involving some of symbolism denoting items considered important to the avifauna present (Weins, 1969). MacArthur & MacArthur (1961) developed a technique to describe the layering of vegetation and concluded that by computing a foliage height diversity, based upon the distribution of vegetation layers, one can predict the bird species diversity of a given community. Sturman (1968) found that canopy volume and upper storey vegetation were significantly correlated with Chikado abundance.

Disproportional use of habitat (macro and micro) is an indication of whether a habitat is used more than available (preferred) or used less than available (avoided). Such a disproportional use of preference of particular vegetation types and habitat characteristics was observed for Kalij, Koklass, Himalayan Monal, Satyr Tragopan and Cheer pheasant. Preference of one vegetation type over other within and between seasons and microhabitat use between the seasons by these species was observed at both the intensive sites (Binsar WS and Pindari reserve forest).

a) Binsar Wildlife sanctuary

Kalij: Kalij used more oak habitat than oak-pine during premonsoon season while it preferred both the habitats equally during postmonsoon season. Summer or premonsoon season is the breeding season for pheasant (Ali & Ripley, 1987 and Grimmett *et al.* 1998). Kalij preferred oak habitat during premonsoon than oak-pine. They preferred this vegetation type when compared to other types within the season but not between the seasons. All the sightings occurred in oak habitat during premonsoon season while 44.44% and 55.56% sightings were in oak and oak-pine habitats respectively. Sathyakumar (1993) and Chandola (1987) also observed similar habitat preference by Kalij over other habitat types in Garhwal Himalaya. It is evident that oak habitat represents close canopy forest and constitutes more plant diversity than oak-pine habitat (Singh *et al.* 1984). The oak habitat is used for foraging, roosting and display. Moreover, decomposed leaves litter renders the humus rich with organic compounds and microfauna (Sharma *et al.* 1993), which may be an additional cause of preference for oak habitat by Kalij. Also, more canopy cover of oak habitat as compared to oak-pine lowered the chances of detection of Kalij by the predators rendering this habitat suitable for Kalij. After reducing the habitat variables by a PCA, the logistic regression was able to successfully classify habitat plots for Kalij presence or absence from PCA factor scores. This suggested that the habitat parameters assessed during this study period were also ones influencing Kalij use of an area. Also Kalij use of an area was not random and there was a definite preference, since the logistic regression was able to differentiate random plots from those in which Kalij was sighted.

During postmonsoon season, the distribution of Kalij was more or less uniform in oak and oak-pine habitats or rather scattered. It may be due to the reason that a significant decline in the food intake of Kalij female is reported during the breeding season because of greater involvement on the part of reproductive activities (Chandola *et al.* 1987). The feeding activity declines after May, the minimal levels are maintained till August and an increase is observed September onwards (Chandola *et al.* 1987). So, this behavioral activity compelled Kalij to utilize other habitats proportionately for acquiring more food. The proportional preference of habitats by Kalij during postmonsoon season was mainly to increase the range of adequate food patches. Kalij maintained pairing during the non-reproductive period and they maintained a constant sex ratio in a study in Garhwal Himalaya (Chandola *et al.* 1987). This could also be one of the reasons that males were confined to the breeding habitat (oak) and accompanied females in other habitats when breeding season was over.

Koklass: Significant difference was observed in the habitat use of Koklass between and within the season in BWS. They preferred oak habitat during premonsoon season than the postmonsoon season. The summer being the breeding season for Koklass (Grimmett *et al.* 1998) it requires cover, an important feature of habitat for pheasant for protection against predators and inclement and safety for breeding hen. The old record (Wilson & Marshal, 1879 and Whistler, 1926) and current literature on Koklass (Gaston *et al.* 1981 and Severinghaus, 1989) suggests that they still prefer well wooded habitats with thick understory vegetation for various activities. Interestingly no sightings have occurred in oak-pine habitat in BWS during premonsoon season. Contrary to this Koklass has been roosting on pine trees and they were encountered in oak-pine habitat (Severinghaus, 1989), which was densely covered with shrubs and occasional oak tree (*Quercus incana*) during premonsoon season at Dungagali in Pakistan. Others (White, 1925 and Latouche, 1931) mentioned pinewoods as being Koklass habitat and Cheng (1963) has reported pine as its roosting habitat and he found that the species was feeding on pine needles. The differential use of habitat by Koklass at various locations may be due to the reasons that pheasants adopt differential pattern of habitat use and movement in response to local habitat conditions (Oslen, 1977) so the regional data on pheasants are not universally applicable (Gatti, 1980). The Koklass population was affected by prevailing local habitat conditions of BWS. During the summers of 1992 and 1995, BWS has experienced worst fire events, which affected large area, and the fire was observed upto the crown height. This caused great damage to the vegetative cover of fire affected areas of the sanctuary. This provided hostile habitat and affected normal behavioral activity during the breeding season. Small portion of oak habitat remained unaffected by fire events. This could be one of the reasons that local and prevailing habitat conditions forced Koklass population in BWS to occupy 100% oak habitat for various ecological activities during the breeding season of 1996. The preference of the species was towards oak-pine habitat during postmonsoon season. This could be due to the reason that the adjacent fire affected oak-pine habitat had recovered ground vegetation and shrubs which has increased feeding material such as herb, grasses, berries and leaves of shrubs because Koklass are largely vegetarian by nature and are frequently grazers by habit (Hume & Marshal, 1879; Blandford, 1898 and Wayre, 1969). Moreover, the feeding activity is increased in terms of area and time in most of the pheasant species when the breeding season is over

(Chandola *et al.* 1987 and Kaul, 1989a). So, Koklass utilized oak pine habitat also in BWS and expanded their range activities for acquiring more food.

b) Pindari Reserve Forest

Kalij: Owing to low sample size of Kalij encountered in different habitat types no general statement could be formulated for premonsoon as well as for postmonsoon seasons for the species. The selected trails in various habitats for monitoring had fallen between the altitude range from 2300-3300m. These trails extended upto subalpine areas, alpine meadows and above but the monitoring was limited to the mentioned altitude ranges only. During my study, including surveys, Kalij has never been encountered above 2600m in Pindari region and it was never seen above 2400m at this intensive study site. They might be present in more numbers at lower altitude but it could not be possible to investigate them in other areas due to some unavoidable circumstances. PCA for premonsoon season could not be performed to extract habitat variable, which could be helpful in explaining variation brought by these between utilized and available macro as well as microhabitat condition by Kalij. There was single sighting of Kalij during premonsoon season and on that basis it is not possible to give reasons for ecological aspects of the species.

During postmonsoon season most of the sightings have occurred in oak and mixed habitats. Though they were seen more in mixed habitat than oak and oak-coniferous but they did not show significant difference between these habitat types during this season. As I observed, habitat utilization was highly influenced by local habitat conditions of Pindari. There were scattered villages and human population with forest clearings used for agricultural purposes. Kalij has been seen feeding in these agricultural fields on Finger millets "*Manduwa*" which might have attracted Kalij from nearby territories to use them as feeding grounds. Similar observation has been recorded in Garhwal Himalaya (Chandola *et al.* 1987) where Kalij was seen feeding Finger millets in the agricultural fields during postmonsoon season. Droppings were found under *Rhododendron arboreum* and *Myrica esculenta* trees in oak habitat indicated that they utilized them for roosting purposes, which confirmed similar habitat type for certain activities in both the seasons throughout the year. Availability and habitat utilization model of microhabitat use indicated that Kalij preferred high tree diversity and shrub diversity areas at lower altitude than other pheasants.

Koklass: Koklass preferred mixed habitat as compared to oak and oak-pine habitats during pre and postmonsoon seasons. Koklass was seen between 2250-3100m altitude range during premonsoon season. 49.15% of Koklass sightings were in mixed while 18.64% and 32.2% were in oak and oak-coniferous habitats respectively. The mixed habitat in Pindari was seasonally grazed by cattle; mostly during post monsoon season (October-July). These grazing lands provided abundant ground vegetation having short height shrub cover, adjacent to which the area was well vegetated by bamboo (ringal) at shrub level. According to Wilson (in Hume & Marshal, 1879), Koklass are largely vegetarian and are frequently grazers by habit. It indicated that mixed habitat where Koklass were seen more as compared to other habitat types provided enough food material as well as nesting site for Koklass. Severinghaus (1990) observed in Pakistan that Koklass lived in association with various kinds of human disturbance. These areas have been created and maintained over the years by *'gujjars'*, seasonally nomadic people with their cattle. Baldwin (in Hume & Marshal, 1879) mentioned that Koklass were never observed in crop fields adjacent to the forests. It seems that Koklass avoids cultivated fields but it utilized man-maintained meadows, if undisturbed. It has been observed that grazing is associated with plant growth and it increase annuals (herbs and grasses) and shrubs (Milchunas & Lauenroth, 1993), and also grazing act as a factor in the conversion of grasslands to shrub land and perennial grassland to annual grassland (Crawley, 1983 and Archer, 1989). Moreover, grasslands also stimulate grasses to produce foliage that is more palatable and richer in diet (Anderson, 1982). So, these man-maintained grazing lands provided sufficient feeding materials during the breeding season and dense shrub cover provided escape cover during and after the breeding seasons from potential predators and also from harsh weather conditions. The utilized habitat differed significantly from those of available microhabitat conditions. Koklass were found in the areas having abundant ground vegetation (herbs and grasses) and shrubs in the partially close canopy forest. These areas also marked the presence of rocks and boulders, which may be utilized as nesting site by Koklass. Roberts (1970) found Koklass nests in such areas. For postmonsoon season, the utilized microhabitat variables showed significant difference on the basis of ground vegetation only. They utilized areas having abundant grasses and herbs in terms of proportion and quantity. Monsoon is the fruiting and flowering season of many Himalayan plant species, which is observed till autumn. The abundance in ground vegetation may have provided abundant food materials such as seeds, berries, shoots and foliage. Available habitat differed significantly from utilized vegetation plots of Koklass on the basis of ground vegetation. Koklass were found in the areas having dense ground cover in the tall open canopy forest.

Himalayan Monal: During premonsoon season (mid-March to mid-June) Monal preferred oak-coniferous habitat than oak and mixed habitats, between altitude range of 2520-3210m. 93.75% sightings of Monal occurred in this altitude range. Oak-coniferous habitat occurred on the northwestern aspect and extended upto ridgeline interspersed with meadows and sub-alpine pastures. The ridgeline portion of this habitat types faced south and southeastern aspects. Due to the presence of snow cover in the higher reaches, there were less exposed ground or rock cover during early summer season. Monal was seen using rocks such as cliffs and forest with rock cover during this season on the south and southeastern aspects, which were less snow covered than other aspects. It has been observed that Monal selected protected ledges on south and southeastern slopes of steep cliff or outjutting masses of boulders for their roosting sites (Beebe, 1918-22). They have been seen to sit on rock outcrop along the cliff for display purposes (Kumar, 1997). These rock outcrops also provided better escape cover to the species. Moreover, Monal also used dense forest areas of oak-coniferous habitat as an escape cover from harsh weather conditions and also as protection from predators. But Monal was never observed to stay in this habitat for longer time. It did not stay at particular altitude range during this season. As the snow started melting at higher reaches a gradual shift of Monal began and it started to move to higher altitude used as breeding ground. Gaston (1981) has observed eight Monals in an area of less than one square km in early April at lower altitude in Himachal Pradesh but at the end of April they had started ascending to higher altitude and few Monal were seen in the area. In Pindari, a Monal nest was found on 10th May on northern aspect at an altitude of 3250m. The nest was on the ground below the rock outcrop at the edge of the oak-coniferous-betula forest near the subalpine zone, which supported that Monal used higher reaches for nesting in the late summer season when snow melted in the rocky area. The utilized microhabitat also reflected the areas associated with dense and diverse tree species and abundant ground vegetation. They utilized dense forest for roosting purposes. One Monal (male) was seen roosting on a branch of tall oak tree (*Quercus semecarpifolia*). Bisht (1990) has observed that Monal utilized temperate forest for roosting in Kedarnath Wildlife Sanctuary during summer. The utilized microhabitat might have provided food materials to Monal during summer. Bisht (1990) has reported that Monal dig the ground with its power beak on the afternoon hour for oak acorn, tubers, roots, shoots, herbs, wild fruits, mosses, and soil insects used as food during summer in Garhwal Himalaya.

During postmonsoon season, Monal preferred oak-coniferous habitat between the altitude range from 2650-3050m. During this season, it utilized slightly narrow altitudinal belt as compared to premonsoon season. It was because of the reason that during the early summer season high altitude areas still had snow cover and received frequent snow fall upto mid summer (March-April) which forced Monal to shift its occupied habitat at lower elevation. As the summer progressed the snow at higher altitude started melting and Monal was observed to move at higher reaches (Gaston, 1981). While during postmonsoon as the winter approached, the higher altitude areas received early snow fall and continued till early mid summer which provided unsuitable habitat for performing various life supporting activities such as roosting, feeding. Interestingly most of the

Monal sightings occurred at the edge of the forest in areas proceeding to meadows with small water bodies in the depressions. October-December is dry season in the Western Himalaya, water become scarce, and also most of the streams dry up at higher altitude due to low temperature during early winter. Monal on many occasions was seen digging wet soil, which might be for drinking water from the seepage. Same observation was observed in Garhwal Himalaya (Kumar, 1997) during autumn. The dense oak-coniferous forest produces deep litter, a characteristic of the temperate broad-leaved forest (Singh & Singh, 1987), and Monal was seen digging in the litter. It might be looking for underground fleshy roots and tubers. Kumar (1997) has observed Monal feeding on tubers and roots of many plant species in Oak-Rhododendron forest in Kedarnath Wildlife Sanctuary in Garhwal Himalaya. Monal is also reported to feed on herbaceous plants, grass roots and mosses (Yonzen & Lelliot, 1981). The utilized microhabitat represented Monal used close canopy dense forest area having abundant ground vegetation and enough litter during this season.

Satyr Tragopan: During premonsoon season, Satyr occupied oak-coniferous and mixed habitat type forests, which provided enough ground vegetation and enough shrub cover. Similar habitat occupancy by Western Tragopan was observed in Pakistan (Islam & Crawford, 1984). In Pindari region the snowfall begins in early November and lasts till March or occasionally till mid April. The Satyr Tragopan therefore appeared to range over large area during summer and was found in all the habitats considered for the study. Studies on Temminck's Tragopan (Shi Hai Tao & Zheng Guang-mei, 1997) showed that the species preferred areas of good cover and abundant bushes during the summer season.

Satyr utilized narrow belt of altitudinal range during premonsoon season (2460-3100m) than the postmonsoon season (2860-3140m) in Pindari. The low altitudinal range utilization was due to the reason that the higher reaches were covered with snow and provided unfavorable habitat conditions.

Premonsoon season coincides with breeding season of Satyr Tragopan when they advertise their presence through calls (Islam & Crawford, 1996). Being a ground dwelling bird, the herb layer probably forms a potential source of food for the Satyr. Summer may also be the season for the commencement of nesting activities (Baker, 1935 and Johnsgard, 1986). Many studies on pheasant (Leite, 1971; Guthery *et al.* 1980 and Reynolds, 1988) have described nest predation and deficiency in nesting habitat as limiting factor for pheasant population. Predation were found to be the proximate factors in influencing nest loss in Sage grouse (Greg *et al.* 1994) and Cobot's Tragopan (Zhang Zheng Wang & Zheng Guang-mei, 1989), but the ultimate cause in these species nest predation was related to the available vegetation. Many workers (Bowmann & Harris, 1980; Redmond *et al.* 1982; Sugden & Beyersbergan, 1986 and Crabtree, 1989) have suggested that tall dense vegetation may act as barrier between predators and ground nesting birds. It is observed that greater amount of tall grass cover and medium height was collectively responsible for lower nest predation (Delong *et al.* 1995). Others (Wallstead & Pyrah, 1974 and Greg *et al.* 1994) have reported that greater amount of shrub cover at nest was associated with non-predation of sage grouse nests. Thus cover at the shrub and ground levels found to be an essential feature of the nesting site and decides fate of the ground nesting birds like the Satyr Tragopan during premonsoon season. The shrub cover predominantly of *Ringal* probably provided the species with vital cover for the nest and also a barrier against predation and nest loss. The relatively open areas with ground cover might have provided food for this ground feeding species and also areas for communication and advertisement.

During postmonsoon season the species preferred oak-coniferous forest as compared to mixed and oak habitats. 75% of the sightings were observed in oak-coniferous and rest was in mixed habitat types. The general utilized microhabitat was represented by open canopy forest with sparse shrubs and dense ground vegetation. Among the habitat variables significant difference was observed for the Satyr habitat plots and non Satyr plots on the basis of ground cover vegetation and shrub richness. It seems that Satyr was more concerned about dense shrub cover irrespective of its species and it utilized this aspect of shrub more or less throughout the area, which formed a very important variable for its distribution. The postmonsoon season was associated with breeding activities like rearing of broods, which needs areas of good cover. Study (Meyers *et al.* 1988) has suggested that survival of Ring-necked pheasant depends in part on the habitat it uses because survival of broods was associated with thicker cover types. In Pindari there was dense growth of *Arundinaria nepalnensis* over large area in association with other species like *Berberis aristata, Pyracantha* sp., *Daphne papyracea* and *Skimmia laureola.* The *Ringal*, which formed the most common cover in the Satyr habitat, provided secure hatching and early brooding. Khaling (1998) has reported similar observation on Satyr habitat use during postmonsoon season in Singhalila National Park in Darjeeling. This inferred that during postmonsoon season the vital breeding requirements necessitated Satyr Tragopan to remain in adequate cover for protection and shelter. Meanwhile abundant ground vegetation cover prevalent during this season apparently provided abundant food to the adults as well as their broods.

CHAPTER 6

FEEDING ECOLOGY

6.1 INTRODUCTION

Food is basic to animal's survival and thus large part of its activities is devoted to procuring these resources. The quality and quantity of food are important that determine many aspects of the physical condition, breeding success and chick survival in several species of birds. There is tremendous radiation in diets of each animal species (Alcock, 1989). Even in some closely related species each member has its own food choice and feeding e.g. the Galapagos finches (Lack, 1971). The traditional dietary hypothesis is that difference in diet among different species show reproductive advantage over others which reduce overlap in their food preferences while other ecologists believe that different diets of species had little or nothing to do with reduction of ecological overlap in food demands (Alcock, 1989).

Faecal studies of mammalian carnivores and herbivores have been used for many years to determine diet composition. These studies largely restricted identification to gross undigested structures, such as chitinous insect's exoskeletons, fur, bones, seeds and pine needles. The first widely used technique was developed for the analysis of squirrel stomach contents (Baumgartner & Martin, 1939). Later, Dusi (1949 & 1952) adapted this technique for faecal analysis of cottontail rabbits (*Sylvilagus floridanus*).

Adams (1957) modified a technique used by Scott (1941) on red fox (*Vulpes* sp.) for analysis of snowshoe hare (*Lepus americanus*) diets. Storr (1961), in Australia, fed perennial and annual dicotyledonous plants to penned quokkas (*Setonix brachyurus*), marsupials with ruminant like digestive systems. He concluded that epidermis survived digestion by virtue of the encasement of entire cell walls in cutin, and that perennial dicots showed no differential breakdown. Succulent annuals, however, survived digestion very poorly. However, a more thorough study in Uganda and Kenya by Stewart (1967) contests this conclusion. He questions the validity of remnant counts because some species fragment digested more readily than others and consequently would appear more important, although intake was the same or less.

There is considerable variation among the phasianids in terms of diet. Kinds of food eaten vary between groups and also by season, and even by habitat in some species, but in most cases food is found just above or below ground level. It includes seed, root, leaves, shoots, flowers, stems, buds, invertebrates and even reptiles (McGowan, 1996). Very little quantitative information is available on the diet of Himalayan pheasants. But it is far sure that diet of pheasants includes all types of food matter and it depends to a large extent on their habitats and the availability of food resources. The present study is on the feeding ecology of Whitecrested Kalij, Koklass, Himalayan Monal and Satyr Tragopan. According to Ali & Ripley (1983) all the pheasants are primarily herbivores but they can be considered as omnivores because sometimes they consume invertebrate also. Hodgson (in Hume and Marshall 1879-1888) found wild fruits, Rhododendron seeds and in some cases entirely aromatic leaves and Daphne in the crop of Satyr Tragopan. Lelliot and Yonzon (1980) during their studies in Central Nepal found the species feeding on the leaf litter and stream debris or on mossy areas. They were also found feeding on the fruits of *Berberis* sp., *Symplocos* sp. and *Rhododendron* sp. From faecal analysis they found leaf, moss, grass, roots, quartz fragments and an insect wing suggesting an omnivorous diet.

Bhandary *et al.* (1986) in Pipar (Central Nepal) found moss and grass leaves as a main autumn diet of the species.

He Fen-Qi *et al.* (1988) studied the feeding behaviour of Chinese Monal (*Lophophorus lhuysii*) and concluded that the main diet was roots, bulbs, leaves and flowers but occasionally insects. Kuehler & Lieberman (1989) studied the diet of Chinese Monal in captivity and observed bird feeding on tubers, grubs, seeds and roots, which would comprise their natural diet. Another study (Yonzen & Lelliot, 1981) on Chinese Monal has been reported to fed on mosses *Rhacomitrium crispulum* and *Bryum* sp., and possibly insects and grubs. Kumar (1997) during his studies in Kedarnath Wildlife Sanctuary observed Himalayan Monal feeding on roots, tubers and moss plant species such as *Gaultheria nummulrioides*, *Anislaea latifilia*, *Satyrium nepalensis*, *Taraxacum offinale* and *Roscoea alpina* etc. On many occasions I also observed Monal digging ground and was feeding on tubers and roots of medicinal plants. Koklass pheasant showed a marked preference for eating the young grass in captivity (Newcombe, 1989). According to Wilson (in Hume & Marshall, 1879) Koklass pheasants are largely vegetarians. Blanford (1898) also reported Koklass feeding on grass and leaves. The species has also been reported feeding on roots, buds and flowers (Wayre, 1969). Chondola-Saklani *et al.* (1987) also reported Koklass feeding on shoots, buds, tubers, leaves, berries, acorns, seeds and insects. Studies conducted on Whitecrested Kalij (Bisht & Chandola, 1986 and Chandola *et al.* 1987) reported seasonal variation in the quality of food intake. During April and May, wheat, barley and *Rubus* seeds were found in the excreta of Kalij and in May and June, *Pinus*, *Mellotus* and *Berberis*. During July to September, which is the sowing months of crops, seeds and seedlings of millet and pulses were consumed along with the insects. In October and November seeds of *Canabis*, *Carrissa* and *Lantana* were present in the faeces of Kalij. These studies were conducted near agricultural field and in forest so crop species were also encountered in the faeces.

Owing to the shy and elusive nature of all the pheasant species it became difficult to have direct observation on feeding. Moreover, being rare and threatened species the killing of these birds is neither permissible nor practicable for crop and gizzard analysis. So, faecal matter analysis was adopted as an alternative method to determine the diet of four pheasant species i.e. Whitecrested Kalij, Koklass, Himalayan Monal and Satyr Tragopan to achieve following objectives from this study-

- Identification of main food items of Whitecrested Kalij, Koklass, Himalayan Monal and Satyr Tragopan.
- Seasonal variation in the diet of different pheasant species.
- Similarity in different pheasant species in context of diet composition.
- Quantification of food items in pheasant species season wise.

6.2 METHODOLOGY

6.2.1 Data collection

The faecal matter (droppings) of pheasant species such as Kalij, Koklass, Himalayan Monal and Satyr Tragopan were collected from Pindari reserve forest. This area was specifically chosen for the study of feeding ecology because all the studied pheasant species were encountered there. Dropping collection was made on the trails, which were used for regular monitoring. After the collection of droppings those plots were cleared to avoid collection of same droppings during subsequent monitoring. The collection was made season wise to compare difference in food items. Droppings were air dried, labeled and sealed in plastic packets and stored in airtight container with camphor. Major ground vegetation species were collected from the places where droppings were found and the collected plant species were identified later. Those plant species were also collected on which pheasants were seen feeding directly.

6.2.2 Preparation of reference slides

Holechek *et al.* (1982) noted that microhistological analysis has been the most widely used method for quantifying the botanical composition of diet and it requires the preparation of reference slides. Reference slide of each plant species was prepared microhistologically and each showed unique epidermal characteristics that allowed easy identification. First of all the plant species were preserved in 10% formalin. Epidermis of plant species were then striped off and then passed through the ascending grades of ethanol for dehydration (30%, 50%, 70%, 90% and 100%) and then cleared in xylol. Permanent slides were made by mounting in Canada Balsam. A total of 40 reference slides of different plant species were prepared.

6.2.3 Preparation of slides of faecal samples

All the droppings of pheasant species were collected season wise to prepare major samples accordingly. The faecal samples were gently crushed by hand. Samples must be ground and sieved to homogenize the size of fragments. Grinding plant fragments can result in loss of recognition of species (Griffiths *et al.* 1974). The sample was cleared in 10% NaOH solution and boiled for 3-4 minutes with 3-4 changes of the NaOH solution.

The excess solution was then drained off and the settled material was poured in a petridish. A dropper extracted 10 sub samples from this sample on 10 glass slides. The sub samples were allowed to air dry later they were mounted in glycerol (Bhandary *et al.* 1986). The slides were examined in 50X and 100X magnification levels interchangeably (Holechek & Valdez, 1985). Plant fragments were counted by recording the frequency of occurrence of them in a microscopic field of view (presence / absence). Every fragment could be identified using reference slides and which fell wholly or partly in the view, was recorded. Although frequency of occurrence tends to over estimate rare and underestimate common species (Hanson, 1970), it is still the most widely used technique. It is expected that the degree of fragility of cuticle differs from species to species (Hercus, 1960; Storr, 1961 and Stewart, 1967) so I made 20 fields / frequencies of observations per slide for ten slides per sample (major sample) to identify and enumerate the proportions of different food items present in the droppings. The identification of invertebrate part in the faecal analysis was also made from the same slides. I however made no attempt to classify different invertebrate parts but only presence / absence of them was recorded from the microscopic view.

6.2.4 Analyses

The prevalence of each food item was expressed as a Food Importance Index (Bhandary *et al.* 1986). According to Beck (1952), the formula needed specific gravity also, which is possible only by crop analysis. In the present studies involving the diet of Himalayan pheasants where crop analysis is not practicable and feasible, only the frequency and composition of food items were considered so the formula used-

Food Importance Index = % Frequency + % Composition/2

Frequency of each food item was calculated by dividing the occurrence of particular food item by all frequencies whereas percent composition was calculated by dividing the occurrence of a particular food item in a sample slide by the total occurrence of all food items.

Sorenson's Similarity Index (Magurran, 1988) was calculated for different pheasant species by taking food items into account. This index was calculated by combining both seasons.

Some food items index fluctuated between seasons so paired sample t–test was performed to observe significant difference between seasons for different pheasant species. Kruskal-Wallis one-way ANOVA and t-test were performed (Zar, 1984) on different food items to observe significant difference among studied pheasant species season wise.

Based on the composition of each food item identified from the droppings of pheasant species was categorized into three groups, 1) Major food components or those food items forming >10% of the total composition; 2) Minor food components or those items forming <10% but >3% and 3) Trace items which formed <3% of the total composition.

6.3 RESULTS

Total 38 food items were identified in Kalij, Koklass, Himalayan Monal and Satyr Tragopan from faecal matter. Out of 38 food items, 36 were plant materials whereas rest were grit and invertebrates. The details of feeding ecology of different pheasant species are described season wise separately.

6.3.1 Diet of different pheasant species in different seasons

6.3.1.1 *Diet of Kalij pheasant from faecal analysis*

Total 11 food items were identified from the droppings of Kalij during premonsoon season. Out of these nine food items were plant material while rest were grits and invertebrate parts. The major food items were *Rubus biflorus*, *Rubus ellipticus*, *Berginea legulata*, *Myrcine africana* and *Fragaria* sp. These food items comprised 61.61% by composition, which were identified for premonsoon season. *Geranium wallichianum*, *Viola* sp., *Thalictrium foliolosum*, *Boeninghausienia albiflora*, invertebrates and grit were minor items and comprised 38.38% by composition whereas no trace items were identified in the droppings of Kalij (Table 6.1). One-way ANOVA did not show significant difference in the composition of different food items identified for premonsoon season ($F = 1.82$, d.f. = 10,100, $p > 0.07$).

In postmonsoon season, total 11 food items were identified. The major food items were *Geranium wallichianum*, *Viola* sp. and invertebrate, which comprised 54% by composition of food items. The minor food items were *Rubus biflorus, Rubus ellipticus, Berginea legulata, Myrcine africana*, *Thalictrium foliolosum*, *Boeninghausienia albiflora*, *Fragaria* sp. and grit and comprised 46% by composition. No trace items were found in postmonsoon season also (Table 6.1). Significant difference in composition of different food items occurred in Kalij droppings ($F = 5.13$, d.f. = 10, 100, $p < 0.00$).

Table 6.1 Food importance index (FII) and different food items found in the droppings of Kalij during premonsoon and postmonsoon season in Pindari reserve forest.

	Premonsoon		Postmonsoon	
Food Items	**FII**	**Category**	**FII**	**Category**
Geranium wallichianum	8.28	Minor	26.3	Major
Rubus biflorus	23.3	Major	6.0	Minor
Rubus ellipticus	21.1	Major	12.8	Minor
Viola sp.	13.5	Minor	29.3	Major
Berginea legulata	15.8	Major	6.75	Minor
Myrcine africana	16.6	Major	6.0	Minor
Thalictrium foliolosum	6.77	Minor	9.75	Minor
Boeninghausienia albiflora	9.03	Minor	6.75	Minor
Fragaria sp.	15.1	Major	11.3	Minor
Invertebrates	10.5	Minor	25.5	Major
Grit	9.03	Minor	9.75	Minor

The food importance index of some food items fluctuated between premonsoon and postmonsoon season such as *Viola* sp., invertebrates, *Geranium wallichianum*, *Rubus biflorus* and *Myrcine africana*. So, Paired sample t-test was performed on the composition of these food items (Table 6.2 & Fig. 6.1). The occurrence of invertebrates during premonsoon and postmonsoon was not significant whereas other food items were significantly different during seasons.

6.3.1.2 *Diet of Koklass pheasant from faecal analysis*

During premonsoon season total 14 food items were identified. *Nerium* sp., Moss and *Fragaria* sp. formed the major food items of the diet, which comprised 41.29% of the food composition. The minor food items consisted of *Daphne papyracea*, *Skimmia laureola*, *Polystichum* sp., *Rubus ellipticus*, *Mondo intermedius*, *Berberis aristata*, invertebrates and grit etc. that comprised 56.12% of the food items. *Pteris biaurita* was the only trace food item (Table 6.3). One-way ANOVA showed significant difference in different food items in premonsoon season ($F = 5.31$, d.f. = 14, 135, $p < 0.00$). Scheff's test showed the difference in *Polystichum* sp. and *Nerium* sp., Moss and *Pteris biaurita*, *Berberis aristata* and *Nerium* sp..

During postmonsoon season, 15 food items were found in the droppings of Koklass. The major food items consisted up of *Athyrium* sp., *Nerium* sp. and *Fragaria* sp. that comprised 43.26% of the food composition. *Daphne papyracea*, *Skimmia laureola*, *Polystichum* sp., *Rubus ellipticus*, *Myrcine africana*, *Potentilla fulgens* etc. was the minor food items, which comprised 52.80% of the food composition (Table 6.3). Trace items comprised 3.93% of food composition and they represented Moss, *Berberis*

Table 6.2 Paired sample t-test value of different food items found in premonsoon and postmonsoon season in Kalij. * = significant

Food items	t-test value	Significance level
Viola sp.	-2.4	$p = 0.03$*
Geranium wallichianum	-2.79	$p = 0.02$*
Rubus biflorus	2.75	$p = 0.02$*
Myrcine africana	2.58	$p = 0.02$*
Invertebrates	-2.09	$p = 0.06$

aristata and invertebrates. *Mondo intermedius* species was totally absent during postmonsoon season whereas *Athyrium* sp. and *Urtica dioca* were found absent during premonsoon season in the faeces of Koklass. Significant difference was observed between different food items ($F = 7.75$, d.f. = 15, 145, $p < 0.00$) and actual difference was observed in *Nerium* sp. with *Rubus ellipticus*, Moss, *Myrcine africana*, *Urtica dioca* and *Berberis aristata.*

Polystichum sp., *Nerium* sp., moss and invertebrates were selected for paired sample t-test and except *Nerium* sp., rest food items showed significant difference in premonsoon and postmonsoon season (Table 6.4 & Fig. 6.2).

6.3.1.3 *Diet of Himalayan Monal from faecal analysis*

A total of 13 food items were identified during premonsoon season in the droppings of Himalayan Monal. The major food items were *Nordostachis jatamansi*, *Potentilla fulgens* and *Artimisea nilgirica*, which comprised 44.44% of composition of food items. The minor food items comprised 50% and they represented *Eulophia compestris*, *Picrorhiza kurroa*, *Achonitum heterophylum*, *Skimmia laureola*, *Ainsliaea* sp., Grit etc. Whereas trace elements were *Satyrium nepalense* and invertebrates, comprised 5.55% of composition (Table 6.5). ANOVA showed significant difference in different food items obtained from the droppings of Monal ($F = 5.22$, d.f. = 12, 126, $p<0.00$). Scheff's test showed significant differences in *Artimisea nilgirica* and *Eulophia compestris*, *Artimisea nilgirica* and *Satyrium nepalense*, *Artimisea nilgirica* and *Picrorhiza kurroa.*

Table 6.3 Food importance index (FII) and different food items found in the droppings of Koklass during premonsoon and postmonsoon season in Pindari reserve forest.

	Premonsoon		Postmonsoon	
Food Items	**FII**	**Category**	**FII**	**Category**
Daphne papyracea	4.93	Minor	7.81	Minor
Skimmia laureola	9.87	Minor	8.59	Minor
Athyrium sp.	-	-	15.62	Major
Polystichum sp.	6.58	Minor	12.49	Minor
Rubus ellipticus	7.40	Minor	5.46	Minor
Nerium sp.	18.92	Major	25.77	Major
Mondo intermedius	10.69	Minor	-	-
Moss	19.74	Major	1.56	Trace
Myrcine africana	4.93	Minor	7.03	Minor
Urtica dioca	-	-	6.25	Minor
Berberis aristata	5.75	Minor	2.34	Trace
Pteris biaurita	3.29	Trace	7.81	Minor
Potentilla fulgens	4.11	Minor	5.46	Minor
Fragaria sp.	13.98	Major	18.74	Major
Invertebrates	7.40	Minor	1.56	Trace
Grit	9.87	Minor	12.49	Major

Table 6.4 Paired sample t-test value of different food items found in premonsoon and postmonsoon season in Koklass. * = significant

Food items	t-test value	Significance level
Polystichum sp.	-2.68	p = 0.02*
Nerium sp.	-0.98	p = 0.34
Moss	4.64	p = 0.001*
Invertebrates	2.68	p = 0.025*

Fig. 6.1 Food composition of Kalij during premonsoon and postmonsoon in Pindari.

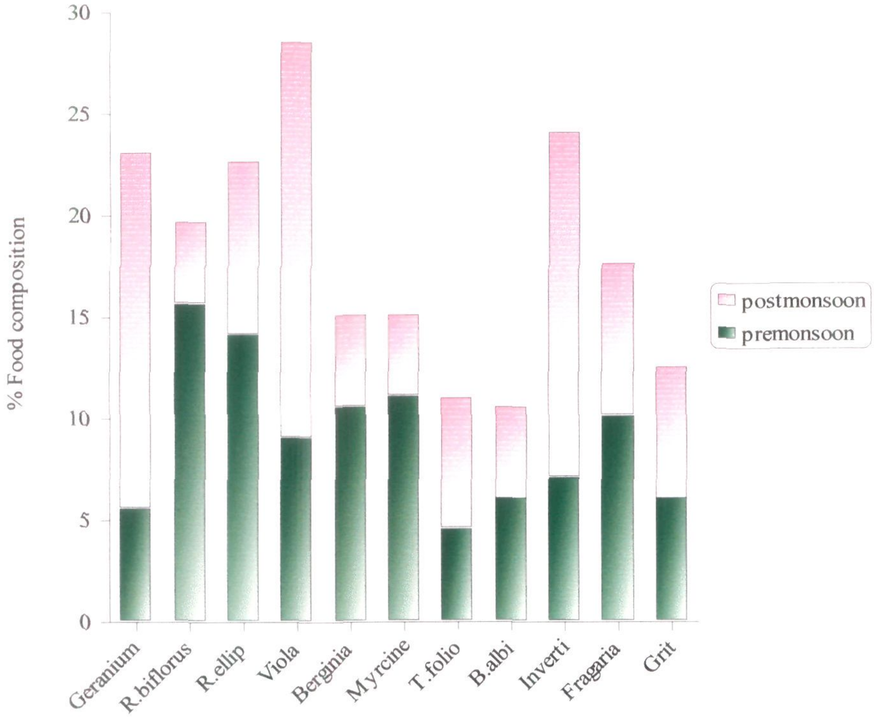
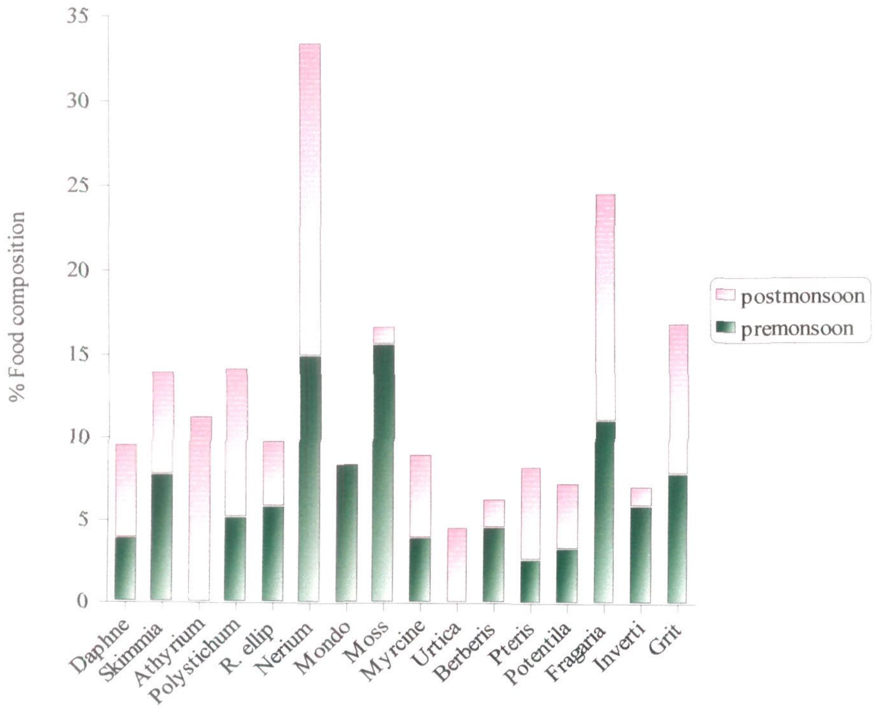


Fig. 6.2 Food composition of Koklass during premonsoon and postmonsoon in Pindari.



During postmonsoon season invertebrates and grit inhered major food items, which comprised 36.58% of the food composition. The minor food items consisted of *Ainsliaea* sp., *Potentilla fulgens*, *Nordostachis jatamansi*, *Picrorhiza kurroa*, *Achonitum heterophylum*, *Hedychium spicatum*, *Skimmia laureola* and Moss that comprised 56.09% of the total food items. The trace items occupied 7.31% of composition of food items and they represented *Satyrium nepalense* and *Gaultheria nummularioides* (Table 6.5). There was significant difference in various food items identified in droppings ($F = 3.56$, d.f. = 12,126, $p<0.00$). Scheff's test did not show significant difference between any food items.

Paired sample t- test showed that out of 13 food items of Monal, the percent composition of three of them fluctuated in both the seasons i.e. *Nordostachis jatamansi*, *Artimisea nilgirica* and grit (Table 6.6 & Fig.6.3). *Hedychium spicatum* was absent in premonsoon while *Eulophia compestris* was absent in postmonsoon season in the faecal matter of Monal.

6.3.1.4 *Diet of Satyr Tragopan from faecal analysis*

The major food items of Satyr Tragopan in premonsoon were *Arundinella nepalensis*, *Cotoneaster acuminata*, *Pilia* sp., *Poa annua* and grit, which comprised 72.27% of the total composition. *Rubus biflorus* and moss that together comprised 8.91% of food composition represented the minor food items. *Daphne papyracea*, *Arisaema flavum*, *Skimmia laureola*, *Polygonum amplexicaule*, *Potentilla fulgens*, *Valeriana wallichii*, *Viola* sp., *Polystichum* sp. and *Pteris biaurita* made up the trace food items and they comprised 18.81% of the identified food composition (Table 6.7). One-way

Table 6.5 Food importance index (FII) and different food items found in the droppings of Himalayan Monal during premonsoon and postmonsoon season in Pindari reserve forest.

	Premonsoon		Postmonsoon	
Food Items	**FII**	**Category**	**FII**	**Category**
Eulophia compestris	3.58	Minor	-	-
Nordostachis jatamansi	9.56	Major	1.72	Trace
Picrorhiza kurroa	4.78	Minor	3.44	Minor
Achonitum heterophylum	4.78	Minor	3.44	Minor
Potentilla fulgens	13.1	Major	6.88	Minor
Artimisea nilgirica	15.5	Major	6.88	Minor
Hedychium spicatum	-	-	3.44	Minor
Skimmia laureola	3.58	Minor	5.16	Minor
Ainsliaea sp.	7.17	Minor	6.88	Minor
Satyrium nepalense	2.39	Trace	1.72	Trace
Gaultheria nummularioides	3.58	Minor	1.72	Trace
Moss	7.17	Minor	3.44	Minor
Invertebrates	2.39	Trace	8.60	Major
Grit	8.36	Minor	17.2	Major

Table 6.6 Paired sample t-test value of different food items found in premonsoon and postmonsoon season in Himalayan Monal. * = significant

Food items	t-test value	Significance level
Nordostachis jatamansi	2.71	p = 0.02*
Artimisea nilgirica	3.35	p = 0.008*
Grit	-0.81	p = 0.43

ANOVA showed significant difference in various food items identified in the droppings of Satyr ($F = 9.01$, d.f. = 15, 144, $p < 0.00$) and Scheff's test showed the difference in the food items *Arundinella nepalensis* with *Arisaema flavum*, *Potentilla fulgens* and *Viola* sp. at 0.05 level of significance.

I identified 17 food items from the faecal droppings of Satyr collected during postmonsoon season. Fifteen of these were plant material. Of these the major food item were *Arundinella nepalensis* and grit, which comprised 24.2% by composition of the postmonsoon food items identified. *Cotoneaster acuminata*, *Rubus biflorus*, *Arisaema flavum*, *Pilia* sp., *Skimmia laureola*, *Daphne papyracea*, *Viola* sp. etc. comprised 75.79% by composition of identified items and recognized as a minor items, while no trace food items were found in postmonsoon season in the diet of Satyr (Table 6.7). Significant difference was observed in various food items ($F = 2.54$, d.f. = 15,144, $p < 0.002$) but Scheff's test did not show any difference in them.

Paired sample t-test showed significant difference in food item *Pilia* sp. ($t = 2.4$, d.f. = 9, $p < 0.04$) during premonsoon and postmonsoon season (Table 6.8). While the percent composition of *Cotoneaster acuminata* and *Poa annua* did not show any significant difference in both the seasons of the Satyr diet (Fig. 6.4).

6.3.2 Comparison in all pheasants

Sorenson's similarity index showed highest similarity between the food composition of Koklass and Satyr ($SI = 0.64$) while Kalij and Monal were least similar in their diet composition ($SI = 0.17$) (Table 6.9).

Table 6.7 Food importance index (FII) and different food items found in the droppings of Satyr Tragopan during premonsoon and postmonsoon season in Pindari reserve forest.

	Premonsoon		Postmonsoon	
Food Items	**FII**	**Category**	**FII**	**Category**
Cotoneaster acuminata	12.9	Major	6.55	Minor
Rubus biflorus	4.98	Minor	4.09	Minor
Arisaema flavum	1.99	Trace	9.82	Minor
Pilia sp.	12.9	Major	4.91	Minor
Skimmia laureola	1.99	Trace	5.73	Minor
Polygonum amplexicaule	1.99	Trace	7.37	Minor
Potentilla fulgens	1.0	Trace	4.91	Minor
Valeriana wallichii	1.99	Trace	7.37	Minor
Daphne papyracae	2.99	Trace	5.73	Minor
Viola sp.	1.0	Trace	9.82	Minor
Arundinella nepalensis	20.9	Major	17.2	Major
Poa annua	10.9	Major	4.09	Minor
Polystichum sp.	1.99	Trace	8.18	Minor
Pteris biaurita	2.99	Trace	6.55	Minor
Moss	3.98	Minor	7.37	Minor
Invertebrates	1.0	Trace	4.91	Minor
Grit	14.9	Major	13.9	Major

Table 6.8 Paired sample t-test value of different food items found in premonsoon and postmonsoon season in Satyr Tragopan. * = significant

Food items	t-test value	Significance level
Cotoneaster acuminata	1.39	$p = 0.19$
Pilia sp.	2.40	$p = 0.04$*
Poa annua	2.05	$p = 0.07$
Arisaema flavum	-3.97	$p = 0.003$*

Table 6.9 Sorenson's Similarity Index in different pheasant species for food composition by combining premonsoon and postmonsoon season of Pindari reserve forest.

	Kalij	Koklass	Himalayan Monal	Satyr
Kalij	1.0	0.45	0.17	0.33
Koklass		1.0	0.40	0.64
Himalayan Monal			1.0	0.38
Satyr Tragopan				1.0

Fig. 6.3 Food composition in Himalayan Monal during premonsoon and postmonsoon in Pindari.

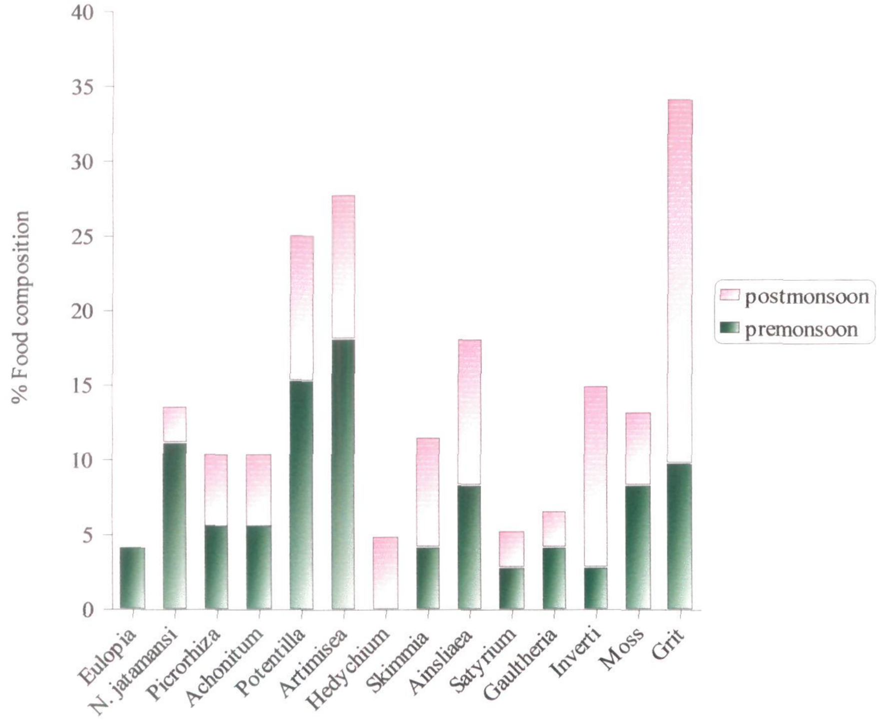
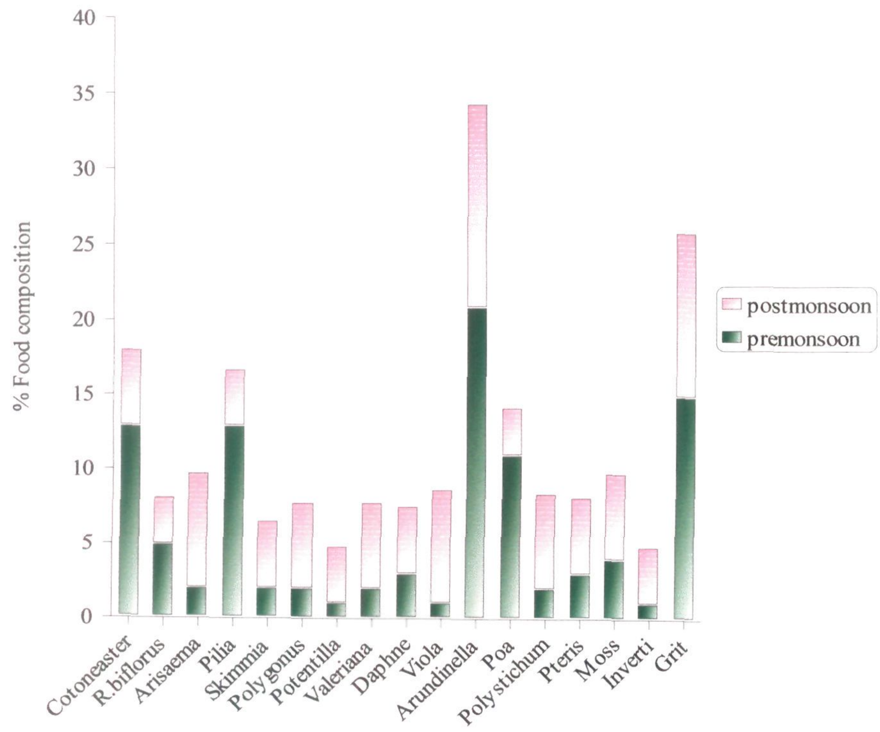


Fig. 6.4 Food composition of Satyr Tragopan during premonsoon and postmonsoon in Pindari.



Grit and invertebrates were the common food items in all pheasants in both the seasons. One-way ANOVA showed significant difference in the percent composition of invertebrates was found in all pheasants ($F = 3.78$, d.f. = 3, 36, $p < 0.018$) during premonsoon season and postmonsoon season ($F = 14.7$, d.f. = 3, 36, $p < 0.00$) (Fig. 6.5). The percent composition of grit was not significantly different in all pheasants in both the seasons (Fig 6.6).

Potentilla fulgens and *Skimmia laureola* plant items were commonly found in the droppings of Koklass, Monal and Satyr. The percent composition of *Potentilla fulgens* was significantly different in these pheasant species ($F = 9.69$, d.f. = 2, 27, $p < 0.001$) during premonsoon season. Scheff's test showed that Koklass used significantly different composition of *Potentilla fulgens* from Satyr and Monal while it was not significantly different for postmonsoon season. Percent composition of *Skimmia laureola* showed significant difference during premonsoon season ($F = 4.66$, d.f. = 2, 27, $p < 0.018$) as well as during postmonsoon season ($F = 3.88$, d.f. = 2, 27, $p < 0.03$) in Koklass, Monal and Satyr diet.

Some food items were found common in these pheasant species so t- test was performed in different food items for different combination of pheasants. The percent composition of *Daphne papyracea* was significantly different in Koklass and Satyr during premonsoon ($t = 3.58$, d.f. = 19, $p < 0.002$) and postmonsoon season ($t = 5.29$, d.f. = 19, $p < 0.00$) while percent composition of *Pteris biaurita* was also significantly different in these two species during premonsoon and postmonsoon season (Table 6.10).

Fig. 6.5 Percent composition of invertebrates in the droppings of pheasant species during premonsoon and postmonsoon season in Pindari.

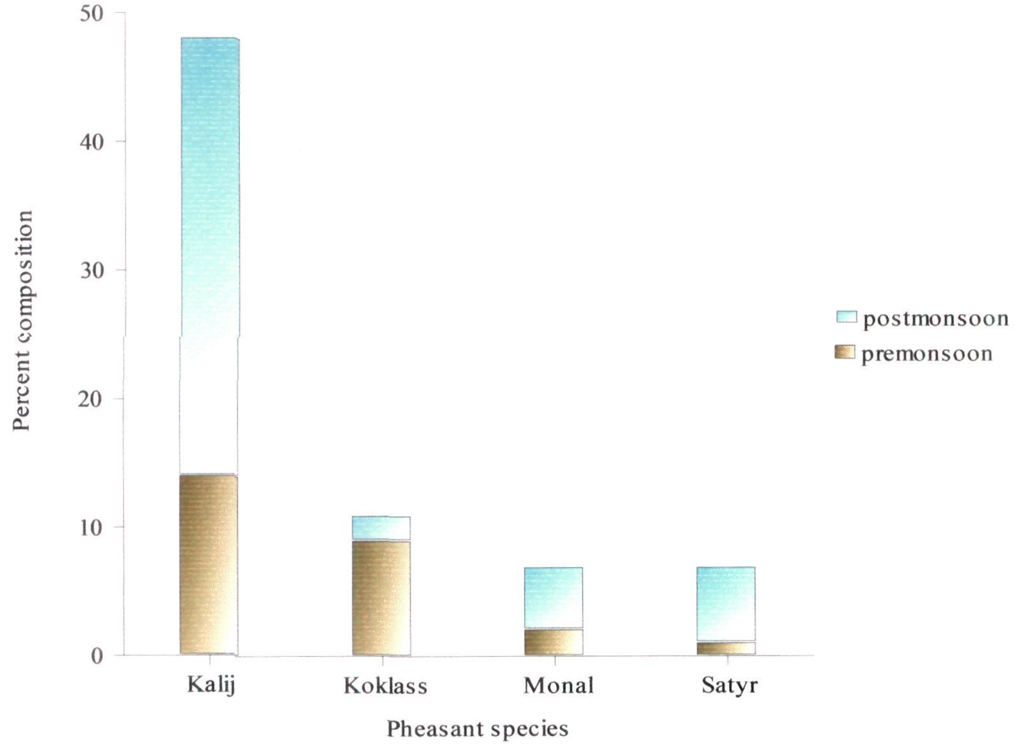


Fig. 6.6 Percent composition of grit in the droppings of pheasant species during premonsoon and postmonsoon season in Pindari.

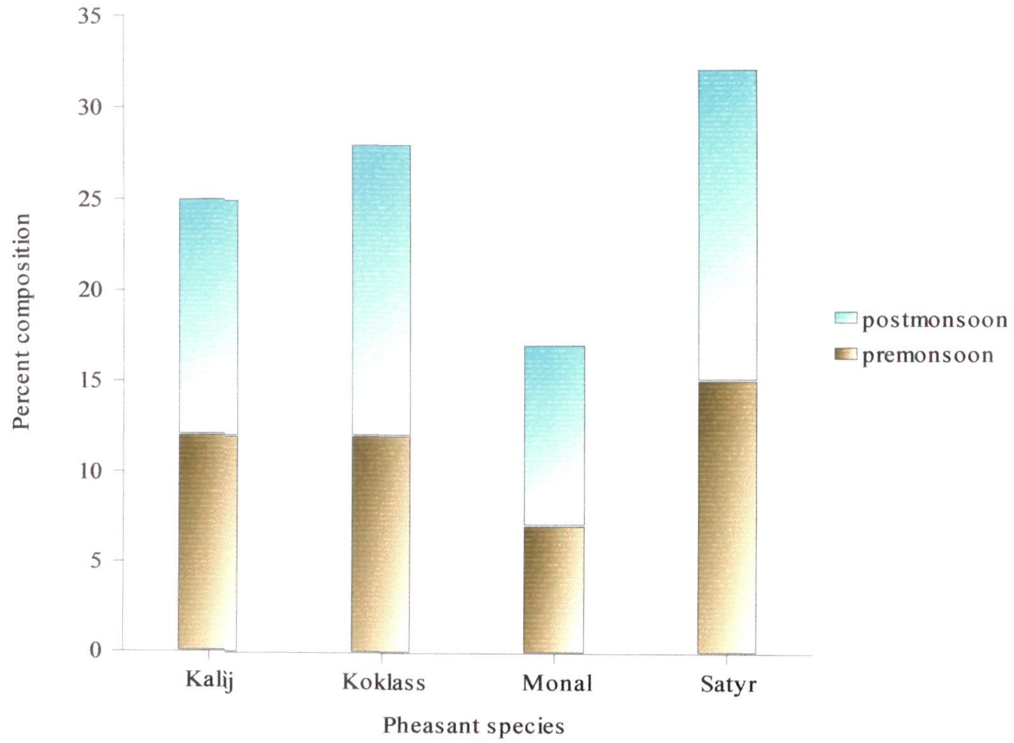


Table 6.10 t-test values for different pheasant species for various food items in premonsoon and postmonsoon season. Ka = Kalij, Kok = Koklass, * = significant

Food items		**Premonsoon**		**Postmonsoon**	
		t- value	**signi.**	**t- value**	**signi.**
Daphne papyracea	Kok & Satyr	3.58	0.002*	5.29	0.00*
Pteris biaurita	Kok & Satyr	2.66	0.15	5.20	0.00*
Rubus biflorus	Ka & Satyr	3.53	0.002*	3.11	0.006*
Myrcine africana	Ka & Kok	4.56	0.00*	3.04	0.007*
Fragaria sp.	Ka & Kok	5.24	0.00*	3.93	0.001*
Rubus ellipticis	Ka & Kok	4.39	0.00*	3.77	0.00*

6.4 DISCUSSION

In a number of studies, determination of diet has been achieved by examining crop or gut contents (Middleton & Chitty, 1937 and Southwood & Cross, 1969), these often coming from shot birds in the hunting season and from caught ones in the breeding months. Today this is neither acceptable for many uncommon species or a necessary method for many others, because a number of other techniques allow the same information to be obtained without the risk of harm or stress to the bird. The use of emetics or other similar methods can be used to collect crop or gut contents from captured wild birds (Pyrs-Jones *et al.* 1974 and Dahlgren, 1982). However unless very carefully used, these methods can stress or in rare cases even kill the bird under observation. Therefore, examination of gut contents should be avoided if possible (Moreby, 1993).

In the present studies, all pheasant species except Kalij, are rare or threatened birds so it was not feasible to collect gut or crop of these species. Faecal analysis came out to be a good method for determining the principal food items throughout the year. Despite the constraints of techniques which prevented detailed quantitative work on the diet of Kalij, Koklass, Satyr Tragopan and Himalayan Monal, the results of this study are vital in determining the diet of the species during different seasons. While extensive studies have been conducted in herbivores (mammals), little analogous work (Khaling, 1998; Kaul, 1989a, b and Moreby, 1993) has been conducted on avian taxa especially for the phasianidae family. Many studies have been conducted on direct observation of feeding behaviour of pheasants such as Zhengje (1989) studied feeding behaviour of Ring-necked pheasant, Jianqiang & Yue (1989) observed the Brown-eared pheasant feeding ecology and 62 plant and animal species recorded. Xiangtao & Xiaoyi (1989) studied the diet and feeding habits of Crimson-bellied Tragopan. According to Stewart (1967) the possibility of identifying all the plant species eaten in the faeces of herbivores is questionable. Martin (1954) was able to recognize 16 species out of 40 in the faeces (and stomach contents) of sheep (*Ovis ories*) and which he suspected were all being ingested. Without proof, he concluded that many species were completely digested or reduced to such small fragments as to be unidentifiable. Croker (1959) could not identify in sheep faeces 1 of about 25 grass species, which were present in the study area. The species she could not find had a thin cuticle, which disintegrated in vitro, and she suspected it had been completely digested. Likewise in the present study on the diet of four pheasant species there may have been a number of plant species present in the study area that were not recorded from faecal analysis. Plant species can be very specific to a particular habitat type and a wide selection of unknown food remains can easily result if a number of birds from different area studied (Moreby, 1993) so only one site was selected as intensive study site for feeding purpose.

The food items identified from the faecal matter of Kalij, Koklass, Monal and Satyr reflected the general if not exclusive diet of these species in the wild because many of the plant species consumed by these species may have undergone complete digestion or may have been reduced to such small fragments that they were not identifiable. Identification is influenced by the distinctiveness of each plant species as well as relative changes in the identifiable characteristics of each plant species as altered by digestion. When plants are succulent, and when the diet is composed of woody and herbaceous plants, the differential rate of digestion lead to highly variable results (Van Dyne, 1968).

Although care was taken and samples were screened through appropriate sieves to remove unusually large items and to obtain a mixture of relatively homogenous size. The Food importance index (FII) gave a general importance for each food item recorded in the diet of these pheasant species for premonsoon and postmonsoon seasons of the year.

Studies revealed that the main diet of all pheasant species was plant matter although invertebrate matter was also present but in low percentage.

During premonsoon season, the *Rubus biflorous, Rubus ellipticus, Berginea legulata* were the main diet of Kalij. The dry conditions were still prevalent in early March or the onset of premonsoon, the evergreen shrubs such as *Rubus biflorus* and *Rubus ellipticus* were the major source of food where as perennials like *Geranium wallichianum*, *Boeninghausienia albiflora* were also present but in minor composition. Such as in Koklass the major food items were *Nerium* sp., Moss and *Fragaria* sp.. *Pteris biaurita* and *Polystichum* sp. (fern) were also present but in traces as they were available in the middle or end of the season. Koklass also ate the leaves of *Daphne papyracea* and *Skimmia laureola* (perennials). In Monal diet, the major sources were medicinal plants such as *Nordostachis jatamansi*, *Potentilla fulgens*, *Artimisea nilgirica.* Other minor parts of the diet were also the medicinal plants. Monal feeds on the roots and leaves of the plant, as has been observed by He Fen-QI *et al.* (1988) for Chinese Monal. In Satyr the *Arundinella nepalensis* formed the major portion of the food. It is a perennial plant that dies after flowering but its leaves were available through out the year. It has a very high content of indigestible fiber and is loaded with abrasive siliceous compounds, which are difficult to eat and digest (Roberts, 1992). The undigested parts are excreted out from the gastrointestinal tract of the Satyr in a highly identifiable form.

During postmonsoon season, the invertebrates formed the major portion of the diet of Kalij. After monsoon the insect availability increases so as in the diet of Kalij. Other species were *Geranium wallichianum* and *Viola* sp., which were in full bloom after monsoon. In the diet of Koklass, the *Athyrium* sp. (fern), *Nerium* sp. and *Fragaria* sp. were the major sources. Although other perennial plants were also present but in low percentage. The *Eulophia compestris* was totally absent from the diet of Monal during postmonsoon season as this herb dies in September. Other medicinal plants such as *Nordostachis jatamansi*, *Picrorhiza kurroa* and *Achonitum heterophylum* also died in late September but the presence in minor composition showed that faecal samples were from August and September also. In Satyr Tragopan, the *Arundinella nepalensis* again formed the major component of the diet. Other than this were *Cotoneaster acuminata*, *Rubus biflorus*, *Ariseama flavum*, *Pilia* sp. as these species were found in full-grown stage in the study area.

In the present study invertebrates formed a minor and trace portion in the diet of all pheasant species. It is however known from studies in Britain that in Galliformes for high survival rates of chicks, a protein rich diet is essential (Green, 1984 and Hill, 1985) and during few weeks of life, this is obtained from insects. Thereafter, the vegetable matter increases until the bird becomes chiefly vegetarian. In this study, I analyzed only adult droppings of all pheasant species and it is apparent that these did not contain a high proportion of invertebrates. However analysis of chick droppings might have revealed a much higher animal content in the diet of the species (Green, 1984 and Hill, 1985).

Another very significant and important component found in the diet of all pheasant species was grit fragments. According to Greely (1962) the major source of calcium and magnesium in the diet of birds like pheasants is grit and levels of 1.09% of calcium in the diet was necessary for full egg production by hen pheasants. Kopischke & Nelson (1966) in their studies in Minnesota and South Dakota observed that laying hens consumed about 50 percent more grit by weight than non-laying hens and they could selectively pick calcium and magnesium bearing grit. Besides, the action of grit in a bird's gizzard grinds the food into a digestible paste. Grit is important if grass forms an important part of the diet (Howman, 1993). The presence of grit in such high percent composition in the diet of the pheasant species around the year may be attributed to the fact that being mainly vegetarians these fragments helped in the grinding of the vegetative matter in the gizzard for proper digestion. According to Sheppard *et al.* (1998), >25% protein is consumed by Himalayan Monal and Kalij pheasant while >20% protein is required by Cheer pheasant and Koklass pheasant and >15% protein is required by Satyr Tragopan. This protein can be taken in animal part or by plant matter. He recommended diet for captive pheasants, which was based on wild birds.

As it has become very much clear from habitat use and distribution of these pheasant species that they all occupy different altitude with a little niche overlap. The lowest similarity was found in Kalij and Monal as Kalij occupies lower altitude than Monal and plant species differ on various altitudes. Koklass had a very wide range of habitat use so this species was moderately similar with other species in context of food items intake.

Faecal analysis is one of the best and widely used techniques for diet determination in rare and threatened species but there were some problems, which I faced during analysis-

- Preparation of reference slides of different parts of plants in areas having a very tedious job although I prepared five slides of different parts of each plant species.
- Many soft bodied annuals and ephemeral species may undergo complete digestion and reduced to very small fragments, which were not recognizable and thus were not recorded.
- On the other hand those plant species, which are high in indigestible fiber content will tend to occur constantly during observation and will be over represented in the diet of the species.
- The quantitative estimation of the diet is quite difficult because the proportion in which the various items represented in the diet may or may not be similar to the proportion in which they were eaten. This is because the digestive processes in the animal's body and the processes of preparing the sample for observation may alter the proportion.
- Working on feeding ecology of four pheasant species at a time is very exhausting job so detailed study should be conducted separately for each species.

In spite of its many difficulties this method was simpler and less time consuming. Since more accurate but highly invasive methods like crop and stomach draining are not practicable on threatened and rare Galliformes species, studies through feeding trials would perhaps be one of the ways for more detailed quantification estimation of the diet of studied pheasant species.

CHAPTER 7

SOCIAL ORGANIZATION

7.1 INTRODUCTION

Pheasants show a variety of patterns of social organization (Ridley, 1982). The works of various naturalists and scientists have established that pheasants vary in gregarious habits, polygamy and paid-bonding (Beebe, 1931; Taber, 1949; Delacour, 1951; Collias & Collias, 1976; McBride *et al.* 1969 and Lelliot, 1981). It has been observed that pheasants maintain different social units during different seasons (breeding and non-breeding). Generally these behavioral attributes bring variation in group size and group composition in species. Ridley (1982) has reported change in group size and sex ratio in Cheer and Blood pheasant when not breeding. Kaul (1989d) has observed flocking in Cheer during winter. Many species such as Tragopan, Peacock pheasant and Argus are solitary but grouping takes place during breeding season (Ridley, 1982). Monals are reported to flock during winter (Beebe, 1918-22 and Kumar, 1997) with different social unit as compared to other seasons of the year. Gaston (1980) assumed an equal sex ratio in many Himalayan pheasants. Islam & Crawford (1993) in their studies on Western Tragopan as well as from other studies suggested a 60:40 (male: female) sex ratio in the species. Studies of Sathyakumar (1993) documented seasonal variation in group size of Whitecrested Kalij while Chandola (1987) reported 1:1 (male: female) sex ratio for Kalij. During this study following problems were taken into account while studying social organization of Kalij, Koklass, Himalayan Monal and Satyr Tragopan in Pindari and Binsar Wildlife Sanctuary-

- To know the group size and group composition of Whitecrested Kalij, Koklass, Himalayan Monal and Satyr Tragopan.
- To verify any change in group size and group structure of Whitecrested Kalij, Kolass, Himalayan Monal and Satyr Tragopan in different seasons.
- Sex ratio of Whitecrested Kalij, Koklass, Himalayan Monal and Satyr Tragopan.

7.2 METHODOLOGY

7.2.1 Data collection

As mentioned in chapter 4 the intensive sites, Binsar WS and Pindari were composed of four trails and each were walked for routine monitoring to acquire evidences of different pheasant species. Random searches in these sites were also conducted within the monitoring area to increase the sample size of different species. For each visual encounter of a pheasant species, following informations were recorded-

- Identification of species
- Group size of each visual evidence for each species
- Sex and age category (adults, juveniles and chicks)

7.2.2 Data analyses

The sample size of visual evidences of all the species at both the sites were found to be low in one season or the other. All the sampling was done in frequencies. So, I performed non-parametric tests (Siegel, 1956) for entire data set. Chi-square goodness of fit was used to determine the differences in group composition between the seasons for both the intensive sites. Same test was also used to determine the difference in the groups containing either sex (all males or all females) or all mixed individuals (male-female) in their groups between the seasons.

All the groups of different pheasant species were separated as having all male groups, all female and both sexes in their groups and Chi-square contingency test was performed to see the difference in either sex individual groups or the groups having both the sexes between the seasons. The groups of different species were also classified as solitary, two or groups having ≥3 individuals and Chi-square contingency test was applied to observe the difference in the group size range between the seasons (Fowler & Cohen, 1986). Descriptive statistics were performed to obtain mean value.

7.3 RESULTS

7.3.1 Binsar Wildlife Sanctuary

7.3.1.1 *Kalij*

Kalij formed variation in aggregation from one to a maximum of 11 individuals in a group across the season in Binsar WS. Overall 66 separate groups of Kalij in the form of solitary bird, paired birds and family groups were obtained while monitoring the trails. The frequency of visual evidences of all male group(s) was 40.9% (27) and that of all female group(s) was 7.4% (7) while 48.48% (14) sightings were of mixed individuals group (male-female). These groups accounted a total of 153 individuals, which comprised of 45% (69) males, 32% (49) females and 22.87% (35) juveniles. The overall mean group size was 2.31 (± 1.81, 95% C.I. = 0.45, n = 66). No significant difference (χ^2 = 2.27, d.f. = 2, $p > 0.05$) was observed in the encounters of solitary birds, paired birds and family groups across the seasons for Kalij. More solitary birds than individuals of two or three (Table 7.2) in a group were encountered (Fig. 7.1). Significant difference ($\chi^2 = 15.89$, d.f. = 2, $p < 0.01$) between the seasons was observed in the encounters of all male groups, all female groups and groups of mixed individuals. Low numbers of groups having only female individuals were encountered. The overall sex ratio calculated was 150 males / 100 females.

During premonsoon season less groups (27) were encountered as compared to postmonsoon season (39) (Table 7.3). The groups comprised 40.7% (11) all male individuals in their groups, 7.4% (2) all female individuals in their groups and 51.85% (14) groups contained male-female in their groups during premonsoon season (Fig. 7.2). While during postmonsoon season, 41.02% (16) visual evidences comprised all male groups, 12.82% (5) groups were of all female groups and 46.15% (18) accounted male-female mixed groups. No significant difference ($\chi^2 = 0.533$, d.f. = 2, $p > 0.05$) was observed between all male groups, all female groups and the groups having both sexes between premonsoon and postmonsoon seasons.

Total 46 and 107 individuals were recorded during premonsoon and postmonsoon seasons respectively. No significant difference ($\chi^2 = 0.08$, d.f. = 1, $p > 0.05$) was observed in the sex composition between the seasons. More solitary individuals (48.14%, n = 13) were seen during premonsoon season but during postmonsoon season either solitary or groups comprising ≥3 individuals were detected more. But no significant difference ($\chi^2 = 4.27$, d.f. = 2, $p > 0.05$) was observed in the group size range (solitary, paired and ≥3 individuals) between the seasons. The mean group size was higher (2.75 ± 1.5, 95% CI = 1.5) for postmonsoon season than premonsoon (1.7 ± 0.78, 95% C.I. = 0.72). More male than the female individuals were available during premonsoon season

Table 7.1 Group size of Kalij and Koklass during premonsoon 96 and postmonsoon 97 in Binsar Wildlife Sanctuary.

Species		Premonsoon 96	Postmonsoon 97	Overall
Kalij	Groups	27	39	66
	Mean	1.77	2.77	2.31
	± S.E.	0.78	1.5	1.81
	95 % C.I.	0.29	0.72	0.45
Koklass	Groups	9	21	30
	Mean	1.22	1.5	1.43
	± S.E.	0.44	0.8	0.72
	95 % C.I.	0.28	0.35	0.25

Table 7.2 Group size range of Kalij and Koklass during premonsoon 96 and postmonsoon 97 in Binsar Wildlife Sanctuary.

		Group size range (%)			
Season	**Species**	**Solitary**	**Two**	**≥Three**	**N**
Premonsoon 96	Kalij	48.14	33.33	18.51	27
Postmonsoon 97		41.02	17.94	41.02	39
Premonsoon 96	Koklass	77.77	22.22	-	7
Postmonsoon 97		61.9	28.5	9.5	21

Table 7.3 Group composition of Kalij and Koklass during premonsoon 96 and postmonsoon 97 in Binsar Wildlife Sanctuary. (AM = all male groups, AF = all female groups, AJM = all juvenile male groups, AJF = all juvenile female groups, TG = Together groups)

		Gender sighting (%)					
Season	**Species**	**AM**	**AF**	**AJM**	**AJF**	**TG**	**Total**
Premonsoon 96	Kalij	40.7	7.4	-	-	51.85	27
Postmonsoon 97		38.4	12.8	2.5	-	46.1	39
Premonsoon 96	Koklass	55.5	22.2	-	-	22,2	9
Postmonsoon 97		38.0	23.8	-	-	38.0	21

Fig 7.1 Overall and seasonwise group size of Kalij in Binsar during 1996-97.

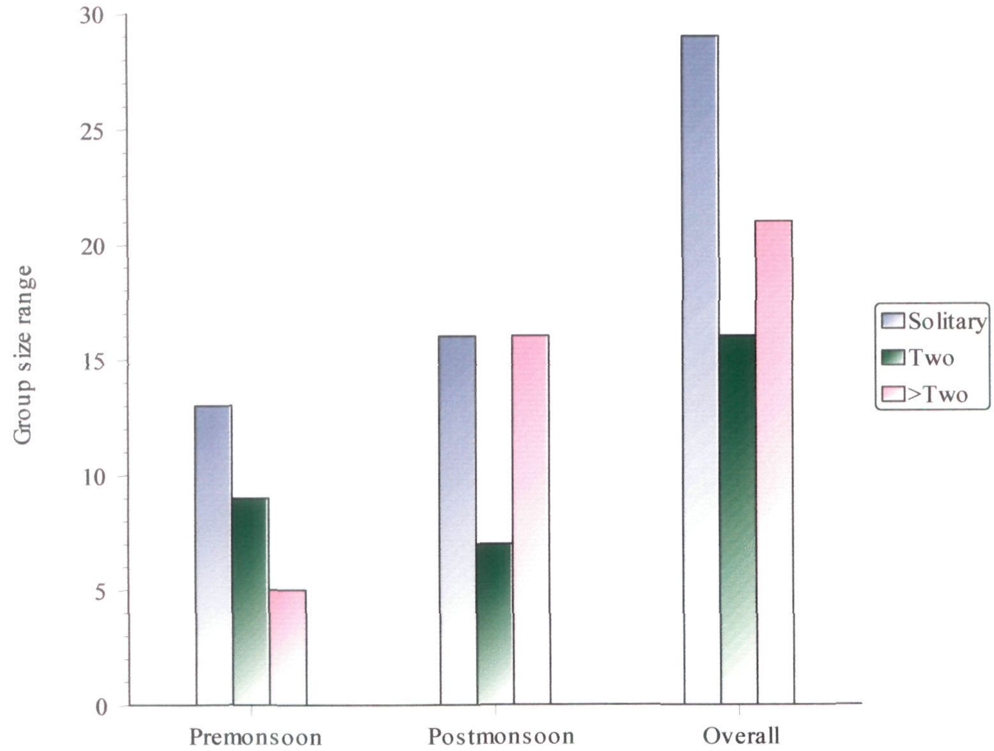
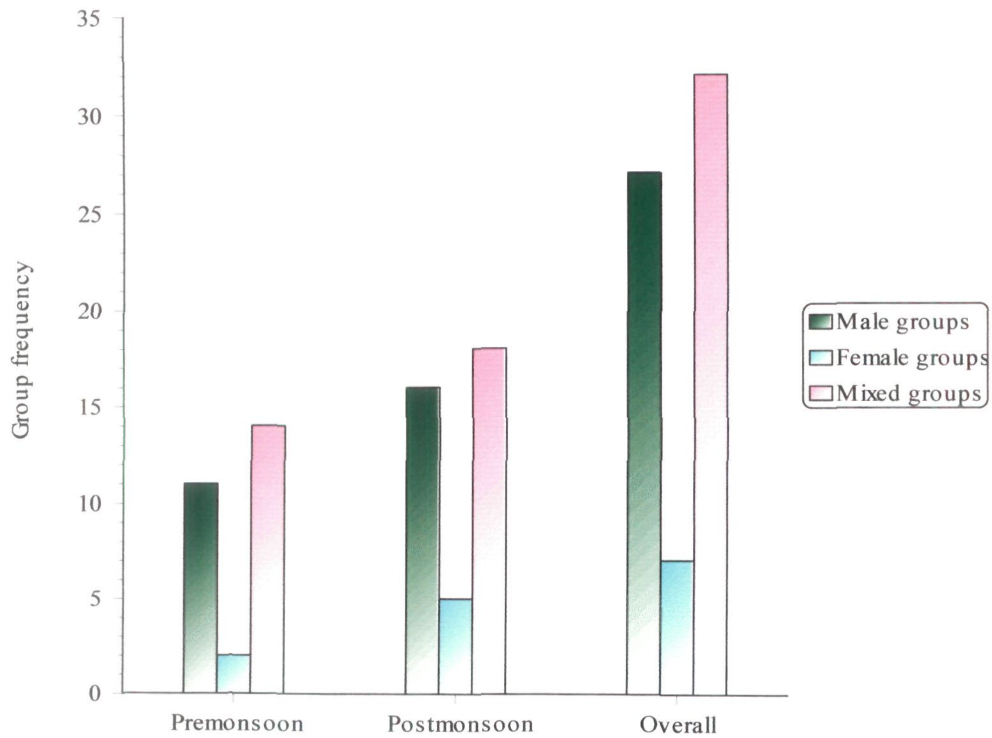


Fig 7.2 Overall and seasonwise group composition of Kalij in Binsar during 1996-97.



than postmonsoon (Table 7.4) and no significant difference was observed ($\chi^2 = 0.361$, d.f. $= 1$, $p > 0.05$) between the seasons. The sex ratio was 137 males / 100 females during postmonsoon season while it was 187 males / 100 females during premonsoon season.

7.3.1.2 *Koklass*

A total of 30 Koklass groups were recorded in two seasons, which comprised nine groups during premonsoon and 21 groups during postmonsoon season. Overall 43.3% (13) groups comprised all male individuals and 23.33% (7) had all female individual groups and on 36.66% (11) occasions they were found together. No significant difference ($\chi^2 = 1.9$, d.f $= 1.9$, $p > 0.05$) was observed across the season in the groups having all males, all females or mixed individuals. While more all male groups were encountered than all female or mixed individual groups during premonsoon (Table 7.1). But during postmonsoon season all male groups and groups of both sexes were seen more than the groups of all female individual groups.

Total 43 individuals were documented from the area during pre and postmonsoon seasons, which comprised 53.5% (23) males and 46.5% (20) females. The groups of premonsoon and postmonsoon seasons included 63% (7) male and 36.36% (4) female individuals while group composition was equal during postmonsoon season (Table 7.4). More solitary individual groups were detected during both the seasons (Fig. 7.3). But significant difference ($\chi^2 = 9.38$, d.f. $= 1$, $p < 0.05$) was observed in the group size range during postmonsoon season and groups containing ≥ 3 individuals were seen more.

The overall mean group size of the Koklass was 1.43 ± 0.72, 95% C.I. $= 0.25$ while it was 1.22 ± 0.44, 95% C.I. $= 0.44$ and 1.5 ± 0.8, 95% C.I. $= 0.35$ for premonsoon

Table 7.4 Sex ratio of Kalij and Koklass during premonsoon 96 and postmonsoon 97 seasons in Binsar Wildlife Sanctuary.

Species	Sex	Premonsoon 96	Postmonsoon 97	Total
Kalij	Male	30	62	92
	Female	16	45	61
	Total	46	107	153
	Sex ratio	187:100	137:100	150:100
Koklass	Male	7	16	23
	Female	4	16	20
	Total	11	32	43
	Sex ratio	175:100	100:100	115:100

Fig 7.3 Overall and season wise group size of Koklass in Binsar during 1996-97.

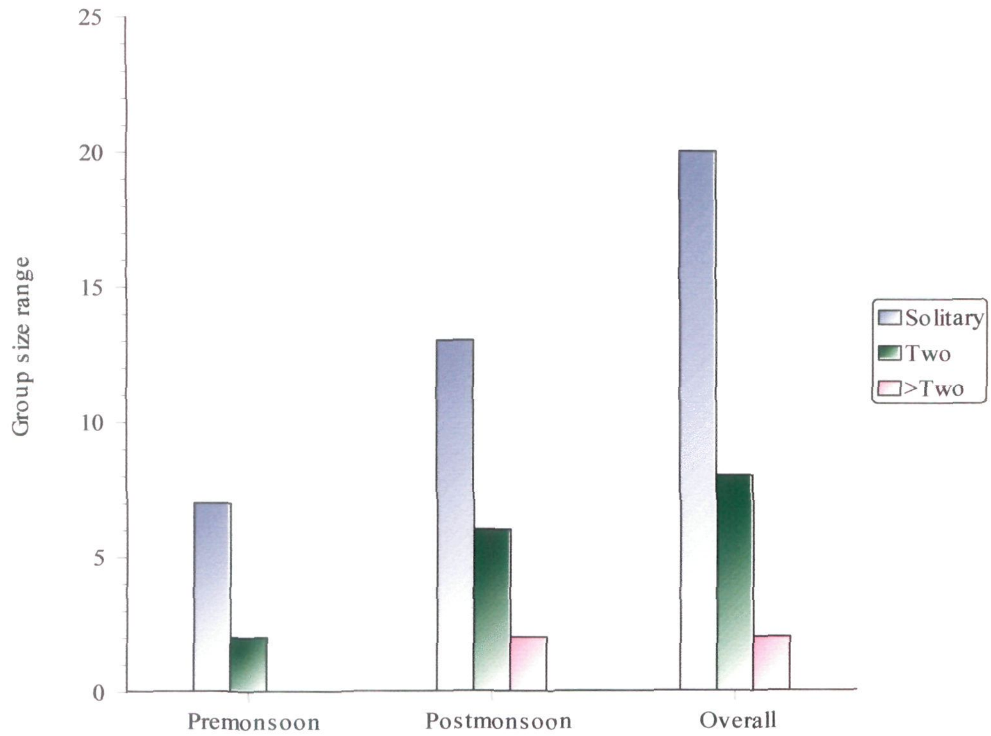
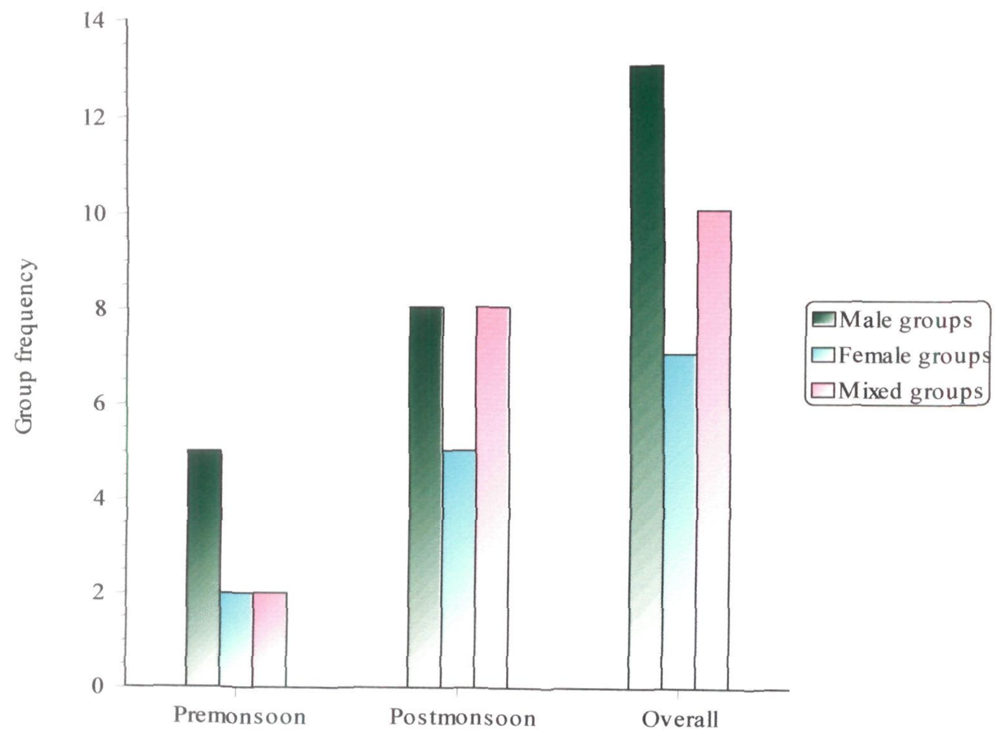


Fig 7.4 Overall and season wise group composition of Koklass in Binsar during 1996-97.



and post monsoon season respectively (Table 7.1). Significant difference ($\chi^2 = 16.81$, d.f. $= 2$, $p < 0.01$) was observed in the encounters of solitary birds, paired birds and family groups across the seasons (Fig. 7.4). More solitary birds than individuals of two or three (Table 7.2) in a group were encountered. The overall sex ratio was 115 males / 100 females while it was 175 males / 100 females during premonsoon season with equal sex ratio during postmonsoon season (Table 7.4).

7.3.2 Pindari Reserve Forest

7.3.2.1 *Kalij*

There were limited encounters with Kalij groups throughout the study period in Pindari. A total of 24 Kalij groups were observed which included 20 sightings during premonsoon and four sightings during postmonsoon seasons. 30% (6) sightings comprised all male individual groups, 25% (5) groups contained all females and 45% (13) groups had mixed individual groups. Groups having both the sexes accounted more during premonsoon (45%, n = 9) than the postmonsoon (100%, n = 4) season.

Total 48 individuals were seen during the entire study period at this site, which included 52.08% (25) male and 47.91% (23) female individuals. The groups encountered during premonsoon season had 48.64% (18) males and 51.37% (19) females, and that of postmonsoon season had 55.55% (5) male and 44.44% (4) female individuals (Fig. 7.6). The overall Kalij groups' envisaged 45.83% (11) solitary individual encounters, 25% (6) paired individual groups and 29.16% (7) groups had ≥3 individuals (Fig. 7.5). More solitary individual groups were detected than the groups having two or ≥3 individuals

Fig 7.5 Overall and seasonwise group size of Kalij in Pindari during 1998.

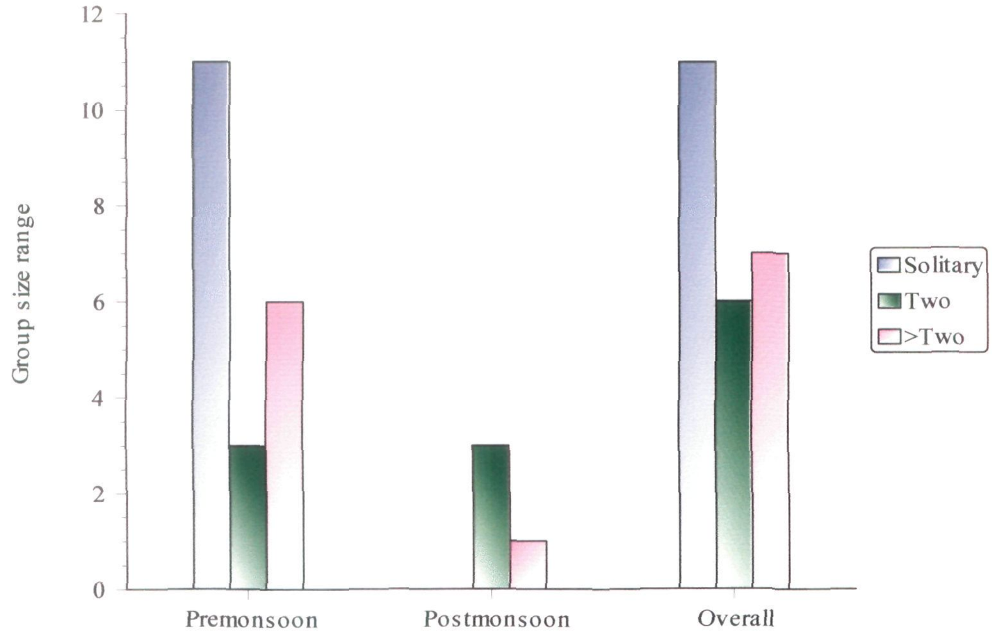
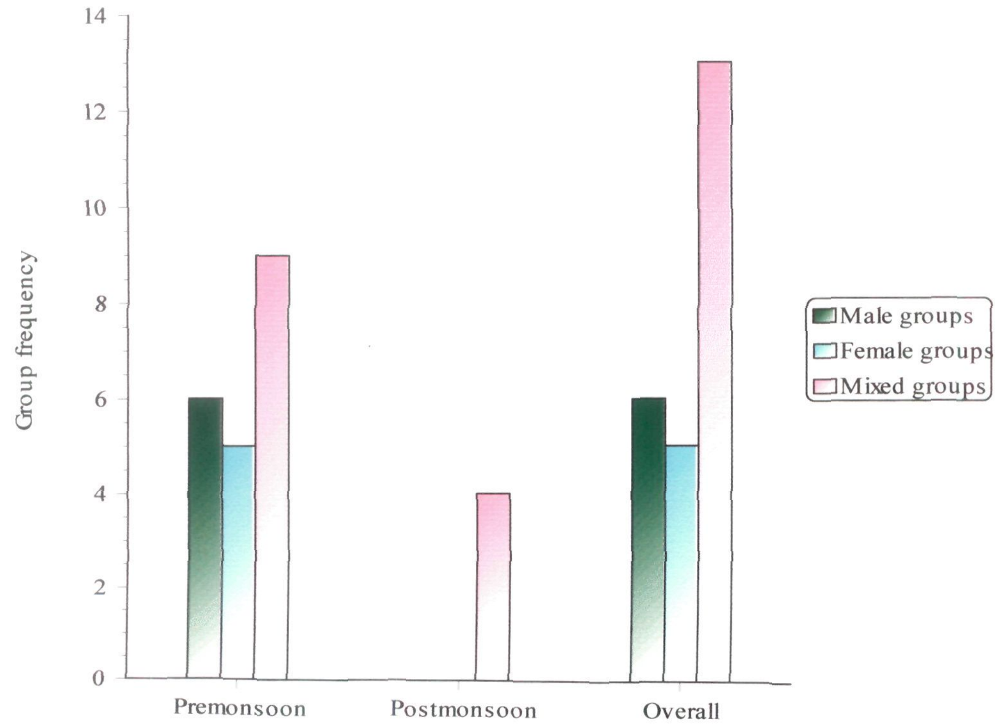


Fig 7.6 Overall and seasonwise group composition of Kalij in Pindari during 1998.



across the seasons. Groups having two individuals were seen more than the solitary or the groups containing ≥3 individuals during postmonsoon season.

The overall mean group size was (1.9 ± 1, 95% C.I. = 0.4) which was similar for premonsoon season with variation in standard deviation (± 0.1) and confidence interval (0.08). The group size for postmonsoon season was 2.25 ± 0.5, 95% C.I. = 0.49 (Tables 7.5 & 7.6). No significant difference ($\chi^2 = 1.75$, d.f. = 2, $p > 0.05$) was observed in the encounters of solitary birds, paired birds and family groups across the seasons. More solitary birds than individuals of two or three (Table 7.7) in a group were encountered. Equal sex ratio (1:1) was observed across the seasons and no significant difference occurred in the sex ratio between the seasons (Table 7.9).

7.3.2.2 *Koklass*

The visual evidences of Koklass obtained 107 groups, which included 59 groups of premonsoon and 48 groups of postmonsoon seasons. Overall 30.8% (33) groups had all male individuals, 21.4% (23) groups had all females in their groups and 47.6% (51) groups had both the sexes. Significant difference ($\chi^2 = 11.67$, d.f = 2, $p < 0.05$) was observed in the groups having either sex or both the sexes in their groups throughout the seasons but no significant difference was ($\chi^2 = 4.10$, d.f. = 2, $p > 0.05$) observed in the groups having either all male, all female or both the sexes in their groups between the seasons (Fig. 7.8). The overall groups comprised 50.82% (92) males, 46.86% (85) females and 2.2% (4) juveniles. Significant difference ($\chi^2 = 33.65$, d.f. = 1, $p < 0.01$) was observed in the group composition between the seasons. More male Koklass were seen during premonsoon season (Table 7.9). The groups seen in both the seasons classified as

Table 7.5 Overall group size of different pheasant species during 1998 in Pindari.

Species	Kalij	Koklass	Monal	Satyr
Groups	25	107	41	13
Mean	1.9	1.7	1.7	1.4
± S.E.	1	0.9	0.9	0.7
95 % C. I.	0.4	0.2	0.3	0.4

Table 7.6 Group size of different pheasant species during premonsoon 98 and postmonsoon 98 in Pindari.

Seasons (95 %)	Species	Groups	Mean	± S.E.	C.I.
Premonsoon 98	Kalij	20	1.9	1.1	0.48
	Koklass	59	1.5	0.6	0.16
	Monal	30	1.4	0.6	0.22
	Satyr	9	1.3	0.5	0.33
Postmonsoon 98	Kalij	5	2.25	0.5	0.49
	Koklass	48	1.9	1.1	0.31
	Monal	11	2.2	1.3	0.78
	Satyr	4	1.5	1.00	0.98

single, two or ≥3 individuals differed significantly ($\chi^2 = 6.37$, d.f. = 2, $p < 0.05$) between pre and postmonsoon seasons (Table 7.7).

The overall group size was 1.7 ± 0.9 (95% C.I. = 0.2). Koklass formed more groups having ≥3 individuals during premonsoon while they preferred to form solitary or two individuals in their groups during postmonsoon season (Fig. 7.7). The sex ratio of the area was 105 males / 100 females. Significant difference (($\chi^2 = 33.65$, d.f. = 1, $p < 0.01$) was observed in the available male-female ratio between the seasons.

7.3.2.3 *Himalayan Monal*

Overall visual evidences yielded 41 Monal groups. Out of this 30 groups were recorded during premonsoon season and 11 groups were recorded during postmonsoon season. Overall 56% (23) groups had all male individuals in their groups, 14.63% (6) groups were all female groups and 29.26% (12) groups contained mixed individuals. Overall significant difference ($\chi^2 = 10.91$, d. f = 2, $p < 0.05$) was observed in the encounters with either sex groups or with mixed individual groups. Statistical test could not be performed to see the difference in encounters with either sex groups or mixed individual groups between the seasons but groups having all male individuals were detected more as compared to all female individual groups or groups having both the sexes. Significant difference ($\chi^2 = 86.91$, d.f = 2, $p < 0.01$) was observed in solitary groups, groups having two or more than two individuals in their groups irrespective of seasons (Fig. 7.9).

Frequencies of Monal groups accounted 66 individuals in total and out of that 68.18% (45) were male individuals, 31.8% (21) were female individuals. During the

Fig 7.7 Overall and seasonwise group size of Koklass in Pindari during 1998.

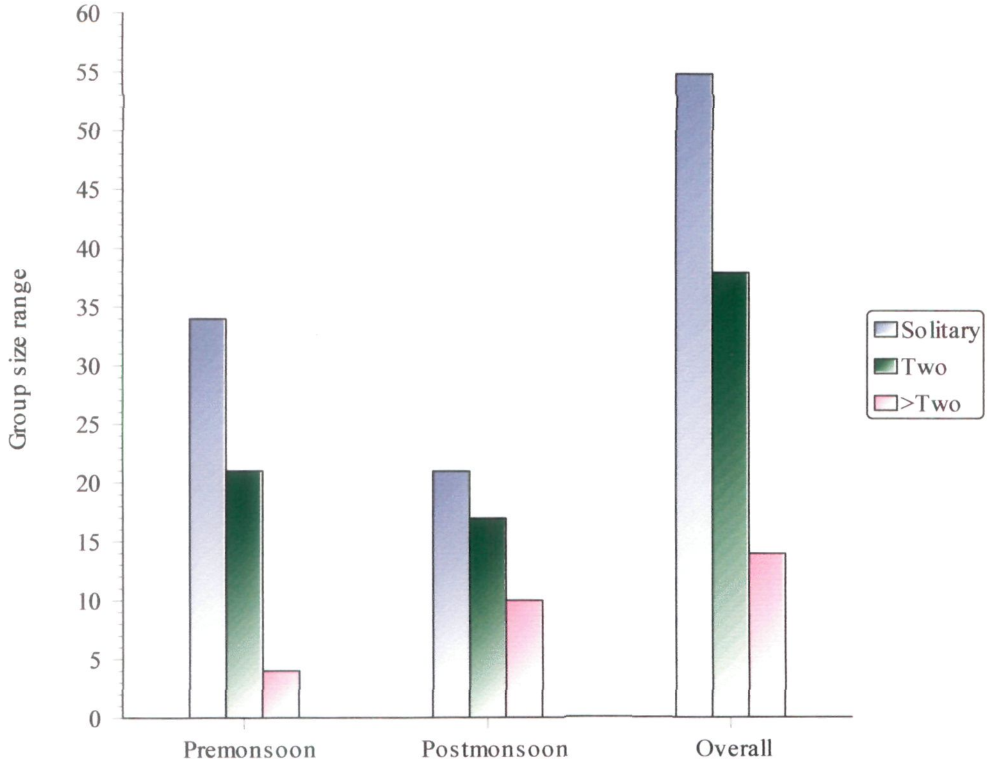
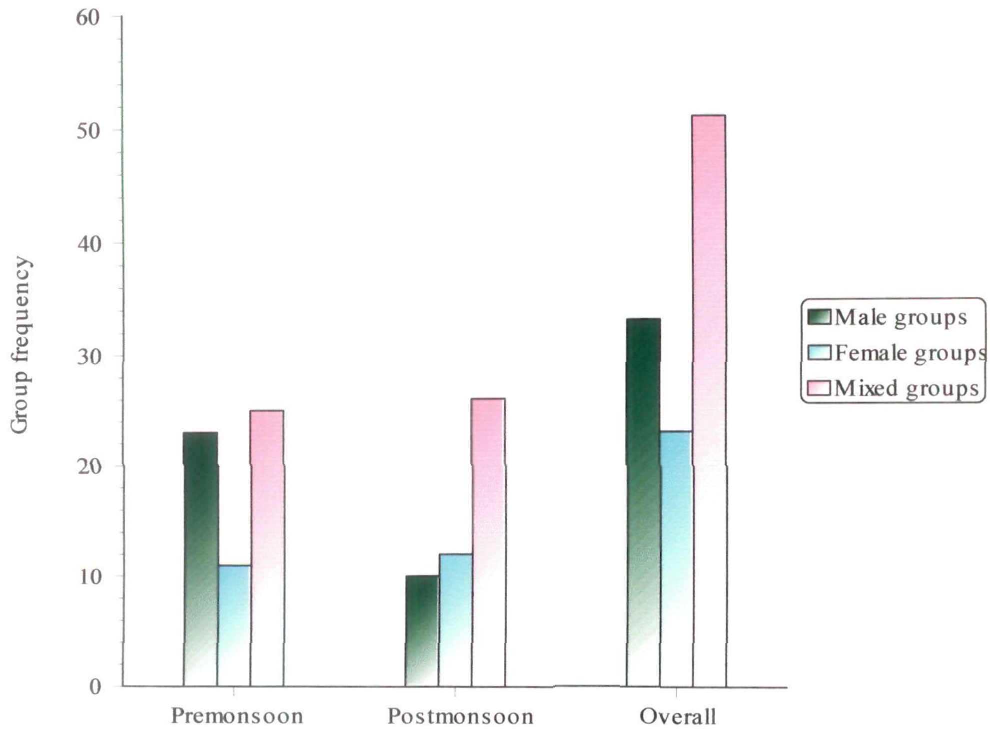


Fig 7.8 Overall and seasonwise group composition of Koklass in Pindari during 1998.



seasons male individuals comprised 66.6% (28) and 70.8% (17) during pre and postmonsoon seasons respectively while female contribution was 33.3% (14) and 29.16% (7) individuals during both the seasons respectively (Fig. 7.10). No statistical test could be performed due to low sample size to see the difference in the group size range between the seasons but more solitary individual groups (20) were encountered during premonsoon season than the postmonsoon season (5).

The overall mean group size for the area was 1.7 ± 0.9 (95% C.I. = 0.3). The mean group size for premonsoon season was smaller (1.4 ± 0.6, 95% C.I. = 0.22) than the postmonsoon season (2.2 ± 1.3, 95% C.I. = 0.79). No test could be performed to see the difference in group size between the seasons. The overall sex ratio for the area was 214 males / 100 females, which differed significantly between the seasons.

7.3.2.4 *Satyr Tragopan*

A total of 13 Satyr groups were recorded from the area, which consisted nine groups from premonsoon, and four groups from postmonsoon seasons. These groups comprised 30.76% (4) groups of all male, 46.15% (6) all females groups and 23% (3) groups represented both sexes (Fig. 7.12). All male individual groups were encountered more during postmonsoon than the premonsoon (Table 7.8).

Total Satyr groups obtained 18 individuals. The overall group composition comprised 50% (9) male individuals and 50% (9) female individuals. Groups encountered during the seasons comprised 33.3% (4) males and 66.6% (8) females during premonsoon while during postmonsoon, 83.33% (5) were male individuals and 16.16% (1) were female individuals (Table 7.9). Overall mean group size for the area was 1.4 ± 0.7, 95%

Fig 7.9 Overall and seasonwise group size of Himalayan Monal in Pindari during 1998.

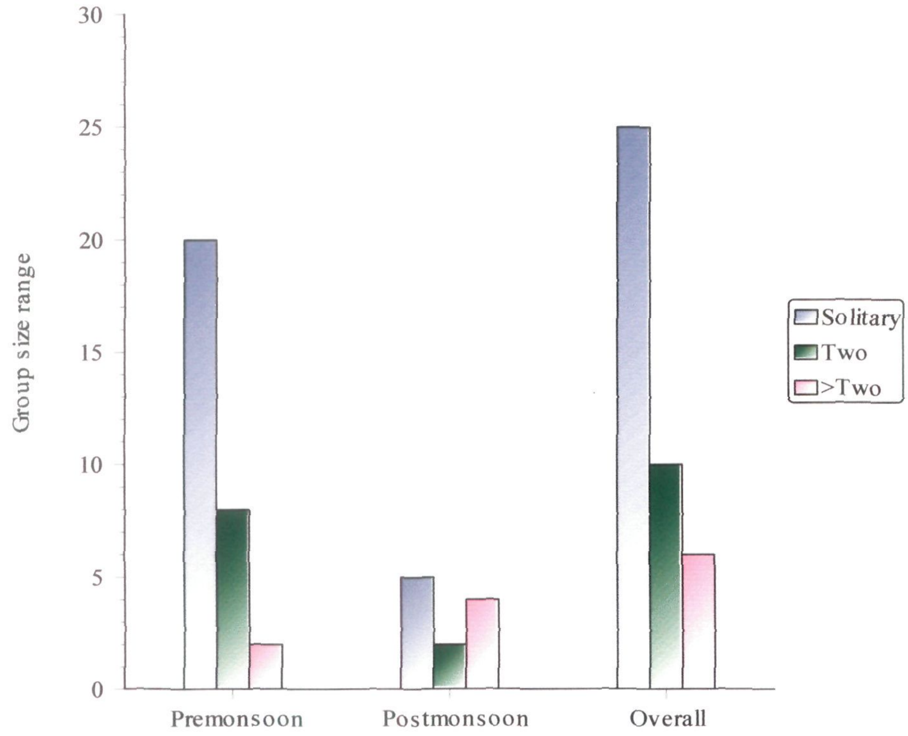
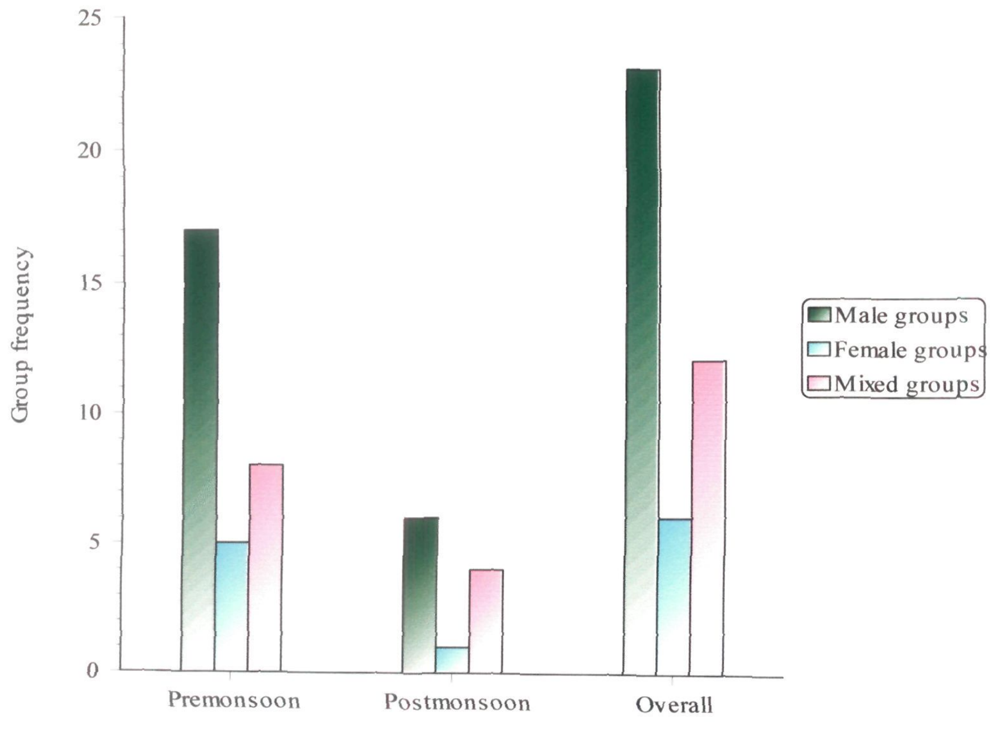


Fig 7.10 Overall and seasonwise group composition of Himalayan Monal in Pindari during 1998.



C.I. = 0.4. No test could be performed for group size to see the difference in the group size range between the seasons. But more solitary individual groups were seen during both the seasons (Fig. 7.11). The overall sex ratio for the species was 100 males / 100 females. It could not be proved statistically but less male were encountered during premonsoon (50 males / 100 females) than the postmonsoon (500 males / 100 females) (Table 7.9).

7.4 DISCUSSION

7.4.1 Kalij

7.4.1.1 *Group size and group structure*

Variation in group size was observed at Binsar and Pindari. The group size ranged from one to eleven individuals in the groups of Kalij in Binsar WS while it ranged from one to four individuals in the groups of Kalij in Pindari.

Apart from male-female groups of Kalij, solitary male and all male groups of Kalij have been sighted frequently in Binsar. A similar trend was observed in a population of Kalij in and around Ranikhet cantonment forest of Kumaon Himalaya (Ahmed, 1995). The solitary males were seen inside the forest while male groups and female groups were encountered at the edge of the forest or just near to forest trails or sometimes on the trails while crossing them. This may be due to the reason that the inside forest provided protection from predators as well as from strangers passing through while they preferred to be in groups when coming out of the forest or sometimes using open spaces for other activities because many bird species gather in flocks while foraging (Saino, 1994). It is also observed that individuals in a group are less likely to be attacked

Table 7.7 Group size range of different pheasant species during premonsoon 98 and postmonsoon 98 in Pindari.

		Group size range (%)			
Season	**Species**	**Solitary**	**Two**	**≥Three**	**N**
Premonsoon 98	Kalij	55	15	30	20
	Koklass	57.6	35.5	6.7	59
	Monal	66.6	26.6	6.6	30
	Satyr	66.6	33.3	-	9
Postmonsoon 98	Kalij	-	75	25	4
	Koklass	43.7	35.4	20.8	48
	Monal	45.4	18.1	36.3	11
	Satyr	75.0	-	25	4

Table 7.8 Group composition of different pheasant species during premonsoon 98 and postmonsoon 98 seasons in Pindari. (AM = all male groups, AF = all female groups, AJM = all juvenile male groups, AJF = all juvenile female groups, TG = Together groups)

		Gender sighting (%)					
Season groups	**Species**	**AM**	**AF**	**AJM**	**AJF**	**TG**	**Total**
Premonsoon 98	Kalij	30	25	-	-	45	20
	Koklass	38.9	18.6	-	-	42.3	59
	Monal	56.6	16.6	-	-	26.6	30
	Satyr	11.1	55.5	-	-	33.3	9
Postmonsoon 98	Kalij	-	-	-	-	100	4
	Koklass	20.8	25.0	-	-	54.1	48
	Monal	54.5	9.0	-	-	36.3	11
	Satyr	75.0	25.0	-	-	-	4

Table 7.9 Sex ratio (Male: Female) of different pheasant species during premonsoon 98 and postmonsoon 98 seasons in Pindari.

Season	Species	Male	Female	Total	Sex ratio
Premonsoon 98	Kalij	18	19	37	94:100
	Koklass	49	40	89	122:100
	Monal	28	14	42	200:100
	Satyr	4	8	12	50:100
Postmonsoon 98	Kalij	5	4	9	125:100
	Koklass	44	48	92	91:100
	Monal	17	7	24	242:100
	Satyr	5	1	6	500:100

Fig 7.11 Overall and seasonwise group size of Satyr Tragopan in Pindari during 1998.

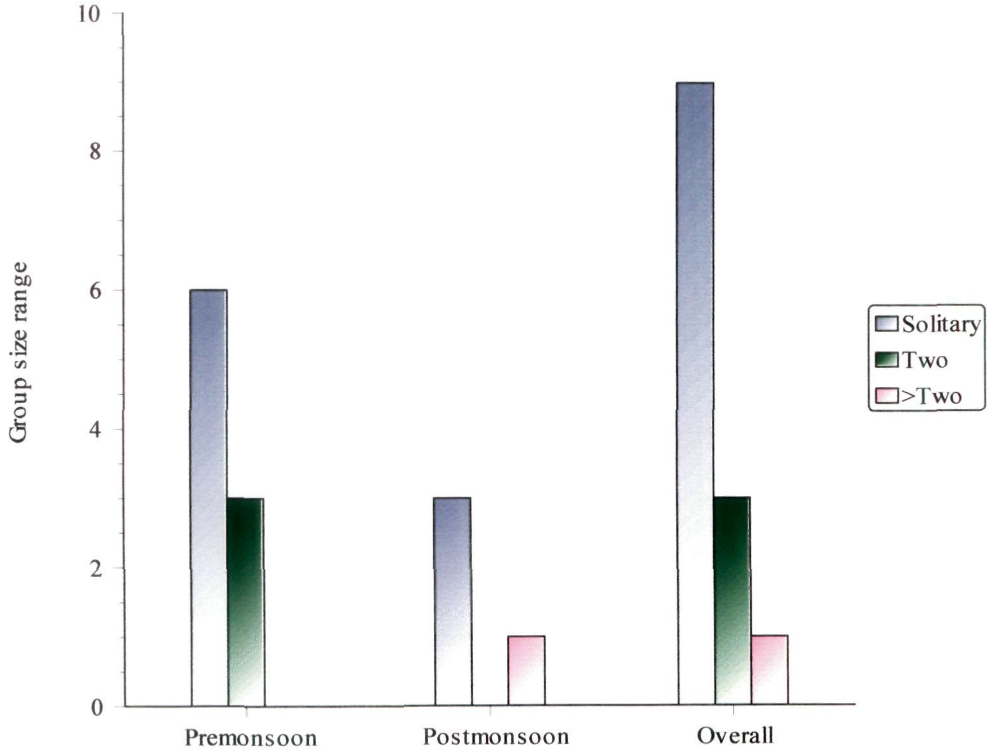
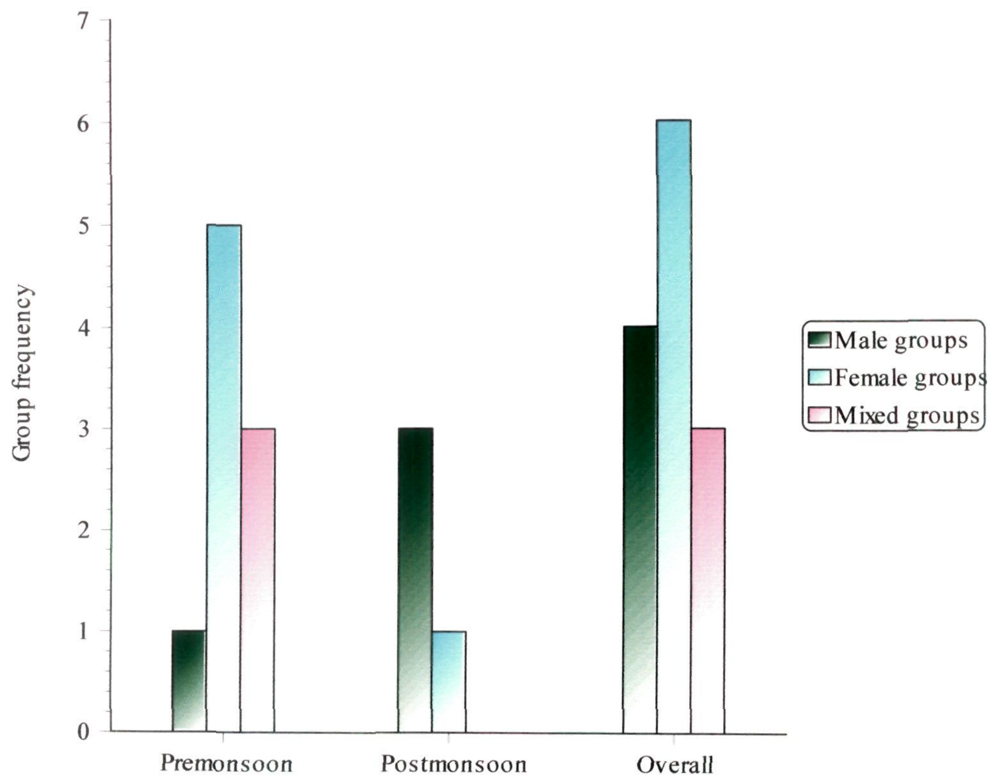


Fig 7.12 Overall and seasonwise group composition of Satyr Tragopan in Pindari during 1998.



by predator than a solitary individual (Kenward, 1978) and an increase in foraging efficiency is also observed (Murton, 1971; Krebs *et al.* 1972; Rubenstein, 1977 and Coraco, 1979). Similar grouping and occupancy of habitat is reported for the Red junglefowl (Johnson, 1963).

More aggregation was observed in the groups of Kalij during postmonsoon season this could be due to the reason that chicks with females were seen in this season and they needed more protection while feeding or for some other activities. Sathyakumar (1993) has also observed increased group size of Kalij during autumn in Kedarnath Wildlife Sanctuary in Garhwal Himalaya.

While in Pindari, male-female groups were frequently encountered than the groups of solitary male or solitary female groups. This could be due to some reasons in this region, which has unique habitat by inhabiting all the representative pheasant species found in Kumaon Himalaya and requires further investigation to explain contradictory statements observed at the other intensive site for the same species.

7.4.1.2 *Sex - ratio*

More males were encountered than the females and ratio remained same during premonsoon and postmonsoon seasons. Sex ratio has been considered of primary importance in population dynamics of species (Dale, 1952) but the results obtained for Kalij gives a false estimate of an unequal sex ratio as well as an underestimate of the density of Kalij population.

An unequal sex ratio is a common bias in sampling. Overestimates of male has been observed in other bird groups such as many species of ducks have shown a marked preponderance of males while Mayers (1939) has reported that males seem to be ten times as numerous as females in many species of Honey-eaters. Moreover, the higher frequency of male sighting may be due to bias in sampling technique. Study conducted on the species (Ahmed, 1995) also obtained different results on sex ratio but data obtained from roosting site provided equal sex ratio for Kalij from the same study, which showed some reliability of the two methods, which can be used for estimating exact sex ratio of the species elsewhere also. But overall equal sex ratio was observed in Pindari by using trail transect/trail monitoring method, which could be by chance. The overall equal sex ratio for Kalij has also been reported from other study (Chandola *et al.* 1987) in Garhwal Himalaya.

7.4.2 Koklass

7.4.2.1 *Group size and group structure*

The frequency of male Koklass was a little higher than the sightings of females in Binsar as well as in Pindari. This could be due to the reason that the males of the species is more conspicuous and brightly colored as is true with other species of the family phasianidae (Delacour, 1986). However, it was my personal experience in the field during my study that females maintained smaller flush distance when they get disturbed with the trespassers as compared to males. The male individuals after detecting the intruder in the field flushed from long distances while females ensconce themselves either on the ground or at the base of any tree or under the shrubs. They remained concealed upto a distance of 2-3 meters and flushed when I approached nearer to this distance. Hence, many of the females might have missed or they must have detected the observer and hide themselves. Moreover, low encounters with females may also be due to sampling technique used for monitoring because unlike the method used by Islam & Crawford (1993) where hunting dogs flushed the birds and both males and females had equal chances of being detected, in my study I used non-invasive technique of trail monitoring.

Solitary individual groups, which comprised solitary males and solitary females, were sighted more as compared to groups of two or more individuals. More paired individual groups were seen at both the sites throughout the year. Holsheimer (1989) has reported Koklass to be rather solitary and monogamous, staying in pairs throughout the year but during the winter, they formed flocks in search of food, but not necessarily in groups. I too observed loose Koklass groups, which cannot be called as true groups but rather individual flocks, feeding in the early winter. Trail monitoring for Koklass population proved to be reliable technique for Pindari while it underestimated Koklass population for Binsar because dawn chorus call count was conducted at both the intensive sites just to have an idea of the presence of the species in these areas. The calls heard at Binsar claimed more breeding male population as compared to encounter of Koklass individuals. While in Pindari area due to its physical characteristic, call counts underestimated Koklass breeding population as compared to visual encounters, which presented more, breeding population in the area.

7.4.2.2 *Sex- ratio*

The overall sex ratio was skewed towards male at both the intensive study sites throughout the year. The same trend of sex ratio was maintained during premonsoon and postmonsoon seasons at both the sites. The sightings of females whether solitary or in groups increased during postmonsoon season, which balanced the male oriented sex ratio, and it was skewed towards females. Koklass being monogamous (Holsheimer, 1989) maintained male oriented sex ratio and as suggested by Johnsgard (1973, 1983), there was an excess of adult males especially in monogamous galliform population. Unequal sex ratio between the seasons at both the sites was due to male skewed sex ratio.

7.4.3 Himalayan Monal

7.4.3.1 *Group size and group structure*

The group size ranged from a solitary individual to four at Pindari. Variation in group size range was observed across the seasons. Large group size was seen during postmonsoon than the premonsoon. This could be due to the reason that in case of Monal, flocks are reported to form only during winter, when the birds are forced into restricted habitat (Beebe, 1918-22). The mean group size of Monal did not vary significantly across the seasons but my observation suggests that during early winter (autumn) Monals appeared to form loose groups. Females appeared gregarious, forming small groups, while males remained more or less solitary. After the first snowfall, temporary but distinct group formation in Monals was seen. But due to their conspicuous plumage a predator in snow would easily spot them. So, they tend to form groups during periods of snowfall (Kumar, 1997) and groups of 3-4 individuals are reported to associate during this non-breeding period (Baker, 1930) probably to avoid predation.

An all male group of four individuals, all females of 2-3 individuals, mixed groups, and solitary males and females have been seen in Pindari. Kumar (1997) has also reported this sort of group formation from his study on the species in Garhwal Himalaya.

7.4.3.2 *Sex ratio*

The obtained result for Monal sex ratio was skewed in favor of males throughout the year. The data obtained during premonsoon and postmonsoon seasons when tested for sex ratio, did not vary significantly between the seasons and showed that it was same for the seasons. Sex ratio across the seasons in Kedarnath WS has been reported to be 1:1 (Sathyakumar, 1993) and 1:1.1 (Kumar, 1997). But variation in the sex ratio at various locations in Kedarnath WS has also been reported from a long-term study (Bisht *et al.* 1989). This study reported male skewed sex ratio. While male-female for Chinese Monal has been reported to be 1:1.08 and 1.27:1 (Lu Tai-Chu *et al.* 1986). In my study, male groups and the groups having mixed individuals were seen more, which resulted male oriented sex ratio across the seasons. Moreover, the conspicuous plumage of males also enhanced chances of being encountered.

7.4.4 Satyr Tragopan

7.4.4.1 *Group size and group structure*

The group size ranged from single individual in a group to a maximum of three individuals. Paired individuals comprised male-female group during breeding season but groups having only male individuals have been encountered during non-breeding period. Inglis (1930), Gaston (1980) and Lelliot & Yonzen (1980) found Satyr Tragopan to be solitary, forming pairs during breeding and in small family units after the chicks are hatched. In this study, results obtained for Satyr Tragopan formed similar group structure across the seasons. Satyr Tragopan except when paired with females were observed singly and were never found in family unit. A group having three male individuals was seen during non-breeding period. Ali & Ripley (1980) and Johnsgard (1986) have suggested that Tragopans live in-groups of 3-4 individuals except during the breeding seasons.

7.4.4.2 *Sex ratio*

Satyr Tragopan population exhibited equal sex ratio in Pindari which validated the 50:50 sex ratio for monogamous gallinaceous birds. However, skewed sex ratio in favour of male in Western Tragopan (Islam & Crawford, 1993) and Satyr Tragopan (Khaling, 1998), and almost equal sex ratio in Cobot's Tragopan (Zhang Junping Zheng Guang-mei, 1989) has been reported. But none of the mentioned studies on different species of Tragopan provided reliable method for the estimation of sex ratio, though the need for intensive study to develop reliable technique for obtaining pheasant sex ratio was felt more than five decades ago (Dale, 1952). As of now sex ratio studies on Himalayan pheasant including Tragopan lack any reliable method and for Satyr, which is rare and threatened population harvest technique is neither applicable nor possible.

8.1 INTRODUCTION

Of the 256 species currently described in the order Galliformes, 68 species are now considered as threatened and out of it 39 (58 percent) are endemic to Asia (Collar & Andrew, 1988). In the order Galliformes, the family phasianidae is the largest single family, which holds maximum number of globally threatened species (Collar & Andrew, 1988). In its distribution range, threats faced by this family are highest in southeast Asia, the Himalayas and China (McGowan, 1996) and the proportion of pheasants that are threatened as a result of man's activities is among the highest in any bird family.

The species belonging to the family phasianidae constitute one of the most beautiful and conspicuous birds of the world and probably of all the species of the order Galliformes, species of this family made the most profound impact on man. The qualities such as beauty, conspicuousness, large size, high protein value of eggs and meat lead to indiscriminate killing of these birds for food and sport, and sometimes for beautiful feathers (Gaston *et al.* 1983) all along their distributional range. For the purpose, overhunting has been one of the main reasons in the reduction of many pheasant species number over the past. Consequently, many of the pheasant species reached at the critical stage of their survival and they have been declared as being endangered with extinction by the international agencies such as IUCN who is concerned with nature and natural resource conservation.

Most of the Asian pheasants are confined to the Himalayas. These Himalayan pheasants are distributed along the narrow temperate zone (50-100 km wide and 2000 km long) intermediate between the tropical and the paleartic zone (Gaston *et al.* 1983). In the entire Himalayan belt, high level of human and livestock population in relation to arable land and general management of land resources resulted deforestation with serious biological consequences (Khoshoo, 1986). The temperate zone as a part of the Himalayas also experienced same consequences, and deforestation of this Himalayan belt lead reduction and fragmentation of forest patches by the extremities of topography and anthropogenic pressures. This reduction in forest area together with fragmented nature of habitat and ecosystem made wildlife species like pheasants of the Himalayan forests particularly vulnerable to local extinction (Diamond, 1974 and Terborgh & Winter, 1980)

WPA / Birdlife / SSC pheasant Specialist Group has identified four major threats for all pheasant species (see Fuller *et al.* 2000). Out of these habitat loss and degradation, hunting for food, sport & trade and human disturbance are the ones that affected the Kalij, Koklass, Cheer, Himalayan Monal and Satyr Tragopan pheasant all along their distribution range.

Kumaon mark the eastern boundary of the Western Himalaya. This region constitutes a significant unit of the Indian Himalayas. The region is heavily populated with human and livestock population throughout the range. Consequently, the area witnessed rapid depletion in its forest area due to developmental activities such as expansion of road network and towns coupled with other intense anthropogenic activities. Yet, the area still holds many pheasant species, including vulnerable Cheer pheasant, which are considered as the bioindicator of the quality of an ecosystem or the habitat they inhabit. To conserve the pheasant species of Kumaon as a flagship for habitat quality this study was carried out and various threats upon surveyed localities in general and pheasants in particular was evaluated with following objectives-

- Evaluation of various localities on the basis of abiotic and biotic pressures.
- To assign conservation value to each pheasant species found in Kumaon
- To assign the conservation value to each locality on the basis of pheasant species conservation
- To prepare a conservation strategy for pheasants housing localities
- Recommendation for the conservation pheasant habitat in general and pheasant species in particular

8.2 METHODOLOGY

8.2.1 Data collection

8.2.1.1 *Abiotic Threats - Fire*

During the surveys of Kumaon, out of 23 surveyed oak patches fire was found at Binsar Wildlife Sanctuary, Jageshwer and Daphiadhura (an oak-forest patch in AWS). A total of 100 plots were sampled at Binsar Wildlife Sanctuary, and 20 & 10 plots were sampled at Daphiadhura and Jageshwer respectively. Circular plot method following Dombois & Ellenberg (1974) was adopted for vegetation sampling in the burnt patches. At each sampling plot a 10m radius circular plot was randomly established to quantify burnt trees. GBH (Girth at Breast Height) in cm, total tree height and height of fire (in meters), and status of tree (dead or alive) were recorded for each tree at each plot.

Regeneration was quantified in terms of seedling and saplings in 3m radius circular plot within the existing 10m radius circular plot. Tree species up to 0.50m was considered as seedling while 0.51-4.0m was taken as sapling. The number of seedlings and sapling of each tree species and their status was recorded within 3m the radius circular plot. The same circular plot was also used for the assessment of shrub layer. Data on ground cover (herbs and grasses) were recorded in four $0.25m^2$ quadrates randomly placed at four places within the 10m radius circular plot.

Data on disturbance factors such as number of cut trees, lopped trees and dung piles were also recorded within the 10m radius circular plot. Besides, occurrence of fire at the rest of the patches was recorded on ordinal scale by interviewing village people and from the forest department.

8.2.1.2 ***Biotic pressures***

Biotic pressures (listed above) were also quantified for each site. Data were collected by means of surveys of oak patches and dependent villages in and around these oak patches. Block Division Office and National Information Center were also consulted for anthropogenic status, literacy rate, land area available and source of income of locals of the surveyed sites. Apart from this, lopping, cutting and grazing were quantified in 10m radius circular plot during the vegetation sampling of each oak patch. Grass harvesting, fuel wood collection, leaf and grass collection, medicinal plant collection, bark and torch wood collection, tourism impact, lichen and moss collection, poaching and animal product trade, timber collection, construction work inside the sanctuaries and protected areas and nomadic pressure were quantified on ordinal scale.

8.2.2 Data analyses

8.2.2.1 *Fire*

Analytical features of fire sampling were computed by following a series of tests. The density and confidence intervals were computed per hectare for trees, seedlings, saplings and shrubs while herbs and grasses were calculated per square meter by the following formula,

Density = Number of individuals / Total area covered

Mean density of each tree species of burnt patch was also calculated. Over all mean tree diversity was calculated by Shannon-Weiner Index (Magurran, 1988) of plant species by following formula,

$H' = -\sum pi \ln pi$ (pi = proportion of individuals found in i^{th} species)

While mean species richness was calculated by Margelef's Index (Magurran, 1988)

$R = S-1/ \ln N$ where S = Number of species, N = Number of individuals.

Trees were categorized arbitrarily into six GBH classes (0-25, 26-50, 51-100, 101-200, 201-400 and >400 cm) and height of fire was also categorized into eight classes i.e. 0-50, 51-100, 101-200, 201-400, 401-800, 801-1600, 1601-3200 and >3200 cm. Tree species diversity and richness was also calculated for different fire height categories and GBH classes by above-mentioned formula. The Importance Value Index (IVI) for each tree species was calculated from the sum of its relative density, relative frequency and relative basal area.

Percentage of overall dead trees and percent dead of each tree species was calculated for each fire affected patches. The Bonferroni confidence intervals were constructed following Neu *et al.* (1974) to detect significant differences in species-specific mortality pattern. To observe the maximum regeneration for tree species, percent regeneration of seedlings of different tree species was also calculated to assess the regeneration pattern.

A chi-square contingency test (Fowler & Cohen, 1986) was performed to find out differential mortality pattern in different GBH class in terms of dead trees and the same test was performed for height categories also.

Top five IVI ranking dead tree species and different GBH classes were taken into account for chi-square contingency test to pin point the association between dead tree species and GBH classes while the same test was performed for top four IVI ranking dead tree species and different height categories to pin point the association between dead tree species and different height categories.

Data for rest of the oak-forest patches where fire did not occur in the recent past were collected on ordinal scale i.e. low, medium and high ratings. In these forest patches occasional occurrence of fire was considered as low (1), medium (2) was taken into account where fire occurred after two years while it was considered high (3) where fire occurred every year.

8.2.2.2 *Biotic pressures*

All parameters of biotic pressures were converted into ratings of low (1), medium (2) and high (3) in the threat context. But the conversion was different for all parameters, which is given below (Table 8.1).

1. **Patch size-** Patch size was considered as a threat to biodiversity conservation. The surveyed oak-forest patches in Kumaon Himalaya ranged from 2.5 km^2 (Jilling in

Naini Tal district) to 54 km² (Gandhura in Pithoragarh district). Keeping in view, the patches falling under the range category between 1-10 km² were considered as small patch size, medium sized patches were considered between 11-20 km² while patches of >20 km² area were considered as large oak forest patches.

2. **Human population-** The human population in and around surveyed oak patches ranged between nil to 20,000 persons. The constant value (density index- persons / km²) was used for each category (low, medium and high). Density index of 0-100 persons / km² was considered as sparsely distributed and 101-200 persons / km² as a medium density while >200 persons / km² were taken into account as densely populated.
3. **Livestock population-** It ranged from nil to 50,000 livestock approximately. Livestock population in a patch from 0-2500 was considered as a low, 2501-7500 livestock as medium and >7500 livestock as a high population. The forest patches having the mentioned dependent livestock population were given ordinal scale ratings of low (1), medium (2) and high (3) respectively.
4. **Number of dependent villages-** The number of dependent villages in and around the surveyed sites ranged from nil to 32. Considering them as threats to biodiversity, the sites having 0-10 dependent villages were given low threat rank, 11-20 dependent villages as a medium threat and >20 dependent villages were considered as high threat upon biodiversity.
5. **Source of income-** The source of income decides amount and kind of dependency of the people on the forest patch. The source of income was also considered as indirect threat to biodiversity in terms of number of income sources available at each

surveyed forest patch. The patches having more than two sources of income exerted low threats, the patches having two income sources were considered as medium while the patches having nil source of income taken as high threat i.e. more dependency on the forests.

6. **Land area occupied by people-** The land available to the locals was calculated by recording the actual land occupied by people living in and around each surveyed oak patch. Later, the land occupied by the locals was calculated in terms of percentage out of the total patch size. The more the land occupied by the locals in and around each oak patch the more threats to biodiversity. It was considered as low threat on forest patch when locals occupied up to 5% of the actual forest patch size, medium threat when they occupied 6-30% land inside the forest patch and high threat when they occupied more than 30% land of the actual oak forest patch.
7. **Percent cultivation on occupied land** - Percent cultivation was calculated from the land area occupied by people settled in and around each oak patch. Cultivation on 0-25 % occupied land was considered as low threat, 26-50% occupied land as a medium and when cultivation was on more than 50% occupied land, it was considered as high threat.
8. **Percent literacy-** Literacy helps in making people aware about the importance of forest and its biodiversity. So, the status of literacy (% literacy) of the local people was taken as the level of threat experienced at each surveyed oak-forest patch. Literacy upto 25% was considered as high threat, 26-50% as medium threat and more than 50% as low threat on the forest and on the biodiversity values of each forest patch.

9. **Lopping**- Within the 10m radius vegetation-sampling plot, total number of trees and the trees lopped was counted. The proportion (%) of trees lopped, out of total trees sampled was calculated and converted into ordinal scale ratings of low, medium and high for each patch. The forest patches experiencing lopping upto 30% were taken as low, 31-60% as medium and more than 60% as high threat.
10. ***Tree cutting***- *Sampling plots were established for assessing vegetation attributes at* each oak-forest patch. Within the vegetation sampling plots number of stumps were also counted. The number of trees and stumps added to quantify the proportion of stumps. Proportion (%) of stumps out of total number of trees counted was calculated for each forest patch. 20% tree cutting was considered as low, 21-40% as medium and more than 40% as high.
11. **Grazing**- Grazing was quantified in terms of dung piles found at each sampling plot at each oak patch. Dung piles found at all the surveyed oak-forest patches were added together and proportion for each oak-forest patch was calculated. The patches falling under 0-25% of dung category were taken as low, 26-50% as medium and more than 50% as high in terms of grazing.
12. **Tapping**- Tapping mainly affects the resin producing tree species. Its frequent and excessive extraction makes the tree species disease and fire prone. Keeping in view, it was also considered as one of the threats to biodiversity. The duration between the two extractions was considered as tapping intensity. The occasional extraction was taken as low tapping, extraction after two years as medium and extraction every-year as high tapping.

13. **Grass harvesting-** Grass harvesting was recorded, as number of bundles (1 bundle = 20 kg approximately) required by each family as fodder for livestock at each oak-forest patch. It was enquired from locals regarding quantity of grass consumed by one domestic animal/day. Each domestic animal required 10 kg / day approx. Range of 0-5 bundles required by single family for their cattle was considered as low grass harvesting, 6-20 bundles as medium and >20 bundles / family required at the patches were taken as high grass harvesting.
14. **Medicinal plants extraction-** The kind of use and purpose of the collection was considered as intensity of threats on biodiversity. The collection of medicinal plants for local use was taken as lower extraction, extraction for local use and some portion of it used for commercial purpose was rated as medium extraction and collection exclusively for commercial purpose was considered as higher extraction.
15. **Fuel wood collection-** Fuel wood harvesting plays a significant and direct role in forest loss all over the world (Myers, 1984). It has also been established that highest rates of forest decline since 1960s have occurred in areas with heavy dependence on fuel wood in developing and non oil producing countries (Ekkholm, 1976; IUCN, 1980; Allen & Barnes 1985 and Postel & Heise, 1988). In the light of above reasons we placed fuel wood collection a great threat to biodiversity. Dependent families and fuel wood collectors were asked for their per day need (kg / day) of fuel wood. 20kg / day / family of fuel wood was required. A family consisted of on an average eight-members so, total wood required by total families of the dependent villages was estimated for each surveyed patch. The estimated required fuel wood was converted in quintals / day from kg / day. The range (minimum-maximum) of fuel wood

required all over the surveyed forest patches were divided in to the ratings of low, medium and high and the patches falling under the categories were provided values accordingly. 0-15 quintal / day was considered as low collection, 15-30 quintals / day as medium and more than 30 quintals / day as high fuel wood collection.

16. **Bark extraction**- The barks of plant species like *Viburnum* sp., *Taxus baccata* and *Abies pindrow* etc. are extracted for medicinal use. The extraction was so heavy that it exposed the plant species to the outer environment. The affected plant species get infected with diseases and become dry after excessive extraction. A sac filled with 50 kg of extracted bark was taken as unit extraction / year. A definite range (sacks / year) was formed for bark extraction for different categories (low, medium and high). Low extraction ranged between 0-25 sacks / year, the medium ranged between 26-75 sacks / year and >75 sacks / year extraction as high.
17. **Tourism**- I considered tourism as threat to biodiversity conservation. Clean and less polluted environmental surrounding of the Kumaon hills attract large number of tourists throughout the year. Towns and surrounding natural habitats (including protected areas) are receiving maximum pressures from the tourist inflow. The town acts as transit camp for providing basic necessities to them but ultimately they go to surrounding natural areas. I collected data for the surveyed oak-forest patches receiving approximate number of tourists every year. The actual numbers were divided in three categories. The patches receiving upto 500 individuals of the tourists experienced low pressure, from 501-1000 as medium pressure and the patches receiving more than 1000 tourists every year were considered as high pressure experiencing from tourism.

18. **Lichen and Moss collection**- Collection / extraction of any forest produce from the forests is threat to them. Except few, lichen and moss collection was observed almost at all the surveyed forest patches. The extraction was mainly for commercial purpose. The unit of quantification was a sac of 50kg. I recorded number of sacks extracted / year at each patch. Extraction upto 25 sacks/year was low, 26-75 sacks / year medium and >75 sacks of lichen and moss extraction was considered as high.
19. **Poaching and animal trade**- Animals are facing severe threat due to poaching activity. Hunting / killing of animals for any purpose was recorded as threats to biodiversity at each site. The killing of the animals was rated with weights (low, medium and high) given to the purpose and the use of the killed animal. The purpose of killing of wild animals differed in different surveyed localities. The aim of killing was enquired from locals. When it was for the personal / local consumption, it was rated as low threat, the killing for the commercial purpose was considered as medium threat to the animals and when the animals were killed for personal / local and commercial purposes then it was thought to be high threat for the animals.
20. **Timber-wood collection**- Not all the tree species were used for timber. Selected timber wood producing tree species were cut for different purposes (house construction, furniture making, bridge construction etc.). The reasons for timber wood collection were responsible to the kind or/type (low, medium and high) of threat experienced at each patch. Timber wood extraction for local use was accounted for low threat to the biodiversity, medium was the threat when it was exclusively extracted for commercial purpose and the high threat when timber wood was extracted for local as well as commercial use.

21. **Construction work**- I considered construction work in and around the surveyed oak patch as direct and indirect threat to biodiversity. Construction work inside the forest is impossible without its clearing. The type of construction work at each site was rated on the ordinal scale of low, medium and high. The construction of houses for locals was considered as low threat because limited space was required for the purpose, while construction work for commercial purposes (Tourist infrastructure, shopping complex, commercial cum residential complex) accounted for medium threat. The areas having all kinds of construction works (for local use, commercial purpose and other big construction work like dams, military operation units etc.) were rated as high threat.
22. **Nomadic pressure**- Excessive grazing by sheep & goats caused great damage to forest. They particularly feed on the regenerating plant species, which decide future status of any forest. The number of grazers was directly related to the intensity of grazing threat to the site. The intensity of threat was recorded on the ordinal scale of low, medium and high. The sites experiencing grazing upto 1000 sheep & goats were taken low nomadic pressure areas while from 1001-5000 sheep & goats as medium and more than 5000 sheep & goats holding areas received high nomadic pressure.

8.2.2.3 *Threat index for the surveyed forest patches*

Each threat parameter was converted into the ordinal scale ratings of low (1), medium (2) and high (3) in terms of threats. To generate threat index (mean threat score) for all the surveyed sites, all the converted ratings of threats were added and divided by number of threat parameters.

Table 8.1 Details of categories taken into account for different biotic threats in Kumaon Himalaya.

Threat	Categories		
	Low	**Medium**	**High**
NVL	1= low (1-10)	2 = med (11-20)	3 = high >20)
HUP/km²	1= low (0-100)	2 = med (101-200)	3 = high (>200)
PSZ (km)	1= small (1-10)	2 = med (11-20)	3 = large (>20)
SOI	1= >2 sources	2 = 2 sources	3 = nill
LA	1= 0-5 % PSZ	2 = 6-30 % PSZ	3 = >30 % PSZ
PRC	1= low (0-25 %)	2 = med (26-50 %)	3 = high (>50 %)
PRL	1= low (0-25 %)	2 = med (26-50 %)	3 = high (>50 %)
LIP	1= low (0-2500)	2 = med (2501-7500)	3 = high (>7500)
LOP	1= low (0-30%)	2 = med (31-60%)	3 = high (>60%)
CUT	1= low (0-20%)	2 = med (21-40%)	3 = high (>40%)
GRAZ	1= low (0-25%)	2 = med (26-50%)	3 = high (>50%)
TAP	1= occasional	2 = after 2 years	3 = every year
GRH	1= low (0-5 bn)	2 = med (6-20 bn)	3 = high (>20 bn)
MP	1= local use	2 = local & comm	3 = commercial
FR	1= occasional	2 = after 2 years	3 = every year
FWC	1= low (0-15 q)	2 = med (16-30 q)	3 = high (>30 q)
BRE	1= 0-25 sacks	2 = 26-75 sacks	3 = >75 sacks
TU	1= 0-500 indv	2 = 501-1000 indv	3 = >1000 indv
LMC	1= 0-25 sacks	2 = 26-75 sacks	3 = >75 sacks
PAT	1= local consmp	2 = commercial	3 = local & comm
TM	1= local consmp	2 = commercial	3 = local & comm
CW	1= own purpose	2 = govt &local	3 = local, govt.& com
NP	1= 0-1000 cattle	2 = 1001-5000 cattle	3 = >5000 cattle

NVL = no.of villages, **HUP** = human population, **PSZ** = patch size, **SOI** = source of income, **LA** = land area owned by locals, **PRC** = percent cultivation, **PRL** = percent literacy, **LIP** = livestock population, **LOP** = lopping, **CUT** = cutting, **GZ** = grazing, **TAP** = tapping, **GRH** = grass harvesting, **MP** = medicinal plant extraction, **FR** = fire, **FWC** = fuel wood collection, **BRE** = bark extraction, **TU** = tourism, **LMC** = lichen & moss collection, **PAT** = poaching and trade, **TM** = timber collection, **CW** = construction work, **NP** = nomadic pressure, **comm** = commercial, **consmp** = consumption, **bn** = bundles (1bn=20kg), **1sack** =50 kg, **q** = quintal

$$\text{Mean threat score} = \frac{\text{Sum of ratings of all threat parameters}}{\text{Total number of threat parameters}}$$

The surveyed sites were categorized, on the basis of generated mean threat score, as the areas having low, medium and high threats. A definite range of mean threat score was given to each threat category. The low threat category was taken between 0-1 mean threat score, the medium threat category between 1.1-2 and >2 mean threat score values were accounted for high threat category.

A Simple Linkage Cluster analysis was performed to classify sites on the basis of threat ratings (low, medium and high). Similar analysis was performed for the sites on presence / absence of threats. Multiple regression analysis was done to see the relationship in four dependency factors viz. human population, source of income, land holding and cattle population with total fuel wood consumption of the families at each site.

The non-parametric test Kendall's tau_ b was used to see the effect of various threat factors on pheasant species composition at various forest patches of Kumaon Himalaya.

8.2.2.4 *Assigning conservation value for different pheasant species*

Combined conservation value for Whitecrested Kalij, Koklass, Himalayan Monal, Satyr Tragopan and Cheer pheasant was calculated for whole Kumaon. Conservation value was also calculated for each surveyed patch on the basis of pheasant species composition. Following six attributes were taken into consideration -

- Altitudinal range occupied by each pheasant species in Kumaon.
- Extent of path size for species abundance.
- Degree of disturbance.
- Degree of restricted distribution of each species in Kumaon.
- Degree of endangerment for each pheasant species.
- Degree of legal status of the area provided to each pheasant species.

The altitude range occupied by Whitecrested Kalij, Koklass, Himalayan Monal, Cheer and Satyr Tragopan was calculated by the differences of the lower and the upper limits of altitudinal range of distribution of each species in Kumaon and it was divided into equal categories with class interval of 500m. It was assumed that small altitude range reflects narrow habitat specificity, as well as a smaller area of occupancy. A distinction was made between altitudinal migrants and non migrants behavioral aspect among considered species, since migrant species occupy a fraction of their altitudinal range at times compared to non-migrant species in the same range. Therefore, migrants were given higher value in comparison with a non-migrant species falling in the same category.

The surveyed sites were categorized into ratings of low, medium and high on the basis of their size. The abundance score of each pheasant species was also categorized in the same manner. The abundance ranking of each pheasant species was correlated with the patch size ranking and the weightage was given accordingly. Species having more abundance score in large patches were assigned more weightage over those species, which were having low abundance score either in small or large forest patch.

The degree of disturbance was calculated for each species by taking following eight disturbance factors into account-

- Lopping
- No. of stumps
- Grazing
- Grass harvesting
- Human population
- Poaching and animal trade
- Medicinal plant extraction
- Nomadic pressure

Human population, poaching and animal trade as well as factors such as lopping, tree cutting, grazing and grass harvesting which directly affect the habitat quality have also been recognized by IUCN (Fuller *et al.* 2000) as direct threat on pheasant species while the medicinal plant extraction and nomadic pressure also emerged as disturbance factors in Kumaon Himalaya.

The disturbance factors were categorized into low, medium and high ratings (Table 8.1). The abundance category of each pheasant species was correlated with threat parameters. The species posing high ranking in each threat parameter was assigned more weightage over others. Each threat parameter was treated separately. The weightage of all threat parameters assigned to each species was summed up to obtain degree of disturbance for each species.

The distribution of different pheasant species was measured on an atlas taking help from the distribution maps provided by Gaston (1982) and Johnsgard (1986) and all the species were ranked according to the portions of their Himalayan ranges falling in Kumaon. The following criteria were used to assign the ranks-

a. Substantial portion of distribution range in the Himalayas.

b. Species endemic to the Himalayas with small range in Kumaon.

c. Species not widespread in the Himalayas with large range in Kumaon.

d. Species widespread in the Himalayas with small range in Kumaon.

The species with a substantial portion of its distribution range in the Himalayas were assigned highest rank. Species endemic to the Himalayas are considered to be more value than those occupying in category c and d, due to their restriction to a narrow range of habitat in the Himalayas. Endemic species are also more susceptible to extinction (Rabinowitz *et al.* 1986). Species not widespread in the Himalayas but having a large range in Kumaon were ranked lower than the species, which are widespread but in small ranges in Kumaon. The widespread species having small ranges may be on the fringes of their Himalayan ranges and these species were assigned lowest rank.

The degree of endangerment for each species was assigned according to the IUCN categories of degree of endangerment (Fuller *et al.* 2000) for different pheasant species of Kumoan. As this conservation strategy is exclusively for Kumaon Himalaya I must consider the status of different pheasant species of Kumaon Himalaya. Keeping this in view, Satyr Tragopan and Himalayan Monal were also given higher weightage over Kalij and Koklass because Monal frequented very narrow range in Kumaon while Satyr Tragopan retain Western Himalayan limit in Kumaon (Gaston, 1982) though the IUCN (Fuller *et al.* 2000) has categorized them into lower risk categories.

All the oak patches have been categorized into different legal status categories maintained by the Government agencies and private owners which are-

- Sanctuaries
- Reserve Forest
- Panchayat Forest
- Unprotected or private Forest

Out of 23 forest patches, Binsar and Askot (comprised 5 surveyed oak forest patches) were the sites, which were enjoying sanctuary status whereas Jilling was the only privately owned forestland included in the surveys. Rest of the oak forest patches had fallen under reserve forest and village Panchayat forest categories. On the basis of presence / absence of different pheasant species in these legal status forest categories, the weightage was assigned. More weightage was given to those species, which were not found in the sanctuaries, as the species found in unprotected areas need strong legal protection for its conservation.

The rank scores of each attribute were converted into a 0-1 scale using the formula following Daniels (1989),

$$\frac{Xi - Xmin}{Xmax - Xmin}$$

where Xi is the rank score of the ith item, Xmin is the minimum rank score obtainable and Xmax is the maximum score obtainable.

The different attributes used in analysis cannot be considered to be equal in their importance to pheasant. Therefore, in order to avoid dilution of importance, attributes were attached different weights. An average of the values of all the attributes were computed for each species using the following formula to give the combined conservation status value (CCSV)-

$$CCSV = \frac{\sum Wi \,.\, Xi + \ldots\ldots\ldots Wn \,.\, Xn}{\sum Wi + \ldots\ldots\ Wn}$$

where Xi is the score of the ith attribute and Wi is the weight of the ith attribute

Conservation value for each surveyed site was calculated by combining the conservation value of each species represented by the sites by using the formula Daniels (1989)-

$$CV = \sum_{1}^{n} CCSVi$$

where CCSVi is the conservation value of ith species and n is the number of pheasant species in each site.

8.2.2.5 *Spatial analysis*

Abundance (encounter rate- groups / 100 man-hours of observation) of different pheasant species and species compositions were used as separate layers for mapping. The threat index and the mean of sets of two threat parameters (i-cutting, lopping, grazing, grass harvesting, human and ii- livestock population and surveyed forest patch size) were used as base layers and the abundance of different pheasant species and compositions at different sites were overlaid for observing trends at various sites.

8.3 RESULTS

Fire caused great damage in Binsar Wildlife Sanctuary, Jageshwer and Daphiadhura.

8.3.1 Overall and species density of vegetation at burnt patches

The density parameter of the community analysis gives an idea of the quantity of the species. Table 8.2 summarizes the mean density (individuals / ha), standard error and confidence interval (95% confidence level) while table 8.3 gives the details of diversity

Table 8.2 Overall density values of vegetation at burnt patches.

Site	Density	± S.E.	C.I. (95% confidence level)
Binsar			
Trees/ha	625.16	23.42	± 45.92
Shrubs/ha	17600.8	976.11	± 1913.13
Herbs/m^2	18.44	2.36	± 1.21
Grass/m^2	27.06	1.41	± 2.75
Seedling/ha	1617.13	129.52	± 253.87
Sapling/ha	693.56	95.81	± 187.79
Daphiadhura			
Trees/ha	538.25	39.44	± 77.31
Shrubs/ha	7271.76	927.9	± 1818.65
Herbs/m^2	35.85	2.73	± 5.36
Grass/m^2	15.86	3.12	± 6.12
Seedling/ha	4883.22	500.82	± 981.59
Sapling/ha	4653.22	591.15	± 1158.64
Jageshwer			
Trees/ha	815.29	89.72	± 175.86
Shrubs/ha	16914.4	3826.75	± 7500.28
Herbs/m^2	16.9	2.66	± 5.23
Grass/m^2	37.0	1.93	± 3.78
Seedling/ha	3290.9	471.96	± 925.02
Sapling/ha	1486.2	591.64	± 1159.6

Table 8.3 Diversity values of the vegetation at burnt patches in Kumaon.

Site	Diversity ± S.D.	Richness ± S.D.
Binsar		
Trees	1.06 ± 0.3	0.99 ± 0.37
Shrubs	1.26 ± 0.45	1.22 ± 0.5
Herbs	0.87 ± 0.48	0.88 ± 0.54
Grass	1.08 ± 0.36	1.02 ± 0.39
Seedling	0.65 ± 0.51	0.81 ± 0.65
Sapling	0.18 ± 0.34	0.24 ± 0.46
Daphiadhura		
Trees	1.21 ± 0.21	1.06 ± 0.32
Shrubs	0.96 ± 0.48	0.98 ± 0.52
Herbs	1.21 ± 0.35	1.05 ± 0.35
Grass	0.56 ± 0.43	0.43 ± 0.36
Seedling	1.08 ± 0.35	1.07 ± 0.34
Sapling	1.12 ± 0.57	1.28 ± 0.69
Jageshwer		
Trees	1.28 ± 0.26	1.14 ± 0.31
Shrubs	0.78 ± 0.42	0.78 ± 0.43
Herbs	1.21 ± 0.55	1.12 ± 0.64
Grass	1.33 ± 0.32	1.17 ± 0.23
Seedling	0.93 ± 0.35	1.02 ± 0.50
Sapling	0.35 ± 0.49	0.37 ± 0.51

and richness for trees, shrubs, herbs, grasses and regenerating tree (seedlings and saplings) species for each site. The maximum mean density (815.29 / ha ± 89.72) of tree species was quantified for Jageshwer and minimum (538.25 / ha ± 39.44) for Daphiadhura in Askot Wildlife Sanctuary. Maximum regeneration in terms of seedlings and saplings of different tree species was observed at Daphiadhura while minimum in Binsar. Tree species diversity (1.28 ± 0.26) and richness (1.14 ± 0.31) was maximum at Jageshwer while minimum diversity (1.06 ± 0.3) and richness (0.99 ± 0.37) was at Binsar.

Mean density of each tree species was also calculated for each site. It was found maximum (277.5 / ha ± 183.14) for *Quercus leucotricophora* in Binsar followed by *Rhododendron arboreum* (190.72 / ha ± 126.14) and *Lyonia ovalifolia* (128.14 / ha ± 76.1) and minimum (31.84 / ha ± 0) for *Euonymous* sp., *Symplocos theifolia, Pyrus pashia, Toona serrata* and *Swida* sp. (Table 8.4). While maximum density (194.26 /ha ± 85.76) was accounted for *Quercus lanuginosa* followed by *Lyonia ovalifolia* (187.89 /ha ± 64.4) and *Rhododendron arboreum* (120.31 ha ± 80.68) at Daphiadhura in Askot Wildlife Sanctuary and minimum (31.84 / ha ± 0) was observed for *Toona serrata, Cedrus deodara, Alnus nepalensis* and *Myrica esculenta* (Table 8.5). *Rhododendron arboreum* had maximum (277.07 / ha ± 175.8) mean tree density followed by *Quercus leucotricophora* (264.33 / ha ± 156.1) and *Lyonia ovalifolia* (133.75 / ha ± 14.35), and minimum (31.84 / ha ± 0) for *Pyrus pashia, Viburnum mullaha* and *Litsea umbrosa* (Table 8.6) in Jageshwer.

Table 8.4 Density of different tree species in Binsar Wildlife Sanctuary.

Species	Density/ha	± S.E.	C.I. (95% confidence level)
Quercus leucotricophora	277.52	3.66	± 36.26
Rhododendron arboreum	190.72	2.81	± 26.35
Lyonia ovalifolia	128.14	1.77	± 16.27
Pinus roxburghii	89.85	4.86	± 25.69
Viburnum mullaha	62.69	2.01	± 11.38
Alnus nepalensis	63.69	5.53	± 20.69
Quercus floribunda	58.79	6.45	± 23.27
Cedrus deodara	74.31	12.01	± 20.8
Swida oblonga	45.11	3.48	± 12.05
Myrica esculenta	39.80	3.61	± 10.21
Pyrus pashia	31.84	0	± 0
Swida sp.	31.84	0	± 0
Symplocos theifolia	31.84	0	± 0
Toona serrata	31.84	0	± 0
Euonymus sp.	31.84	0	± 0

Table 8.5 Density of different tree species in Daphiadhura.

Species	Density/ha	± S.E.	C.I. (95% confidence level)
Quercus lanuginosa	194.26	8.41	± 37.59
Lyonia ovalifolia	187.89	6.31	± 28.22
Rhododendron arboreum	120.31	8.79	± 37.27
Swida oblonga	110.01	11.45	± 37.98
Alnus nepalensis	31.84	0	± 0
Quercus leucotricophora	63.69	0	± 0
Praxinus micrantha	47.77	22.07	± 31.21
Quercus floribunda	31.84	0	± 0
Toona serrata	31.84	0	± 0
Cedrus deodara	31.84	0	± 0
Myrica esculenta	31.84	0	± 0

Table 8.6 Density of different tree species in Jageshwer.

Species	Density/ha	± S.E.	C.I. (95% confidence level)
Quercus leucotricophora	264.33	30.59	± 96.75
Rhododendron arboreum	277.07	34.45	± 108.95
Lyonia ovalifolia	133.75	14.35	± 45.39
Myrica esculenta	127.38	26.75	± 70.77
Pinus roxburghii	76.43	14.23	± 31.83
Viburnum mullaha	31.84	0	± 0
Pyrus pashia	31.84	0	± 0
Litsea umbrosa	31.84	0	± 0

8.3.2 Survival and mortality rate of species

Fire directly affects plant growth, survival and reproduction and can impact the dynamics of seed and regeneration (Bond & van Wilgen, 1996). Each tree species showed different response towards fire. Consequently, a differential survival and mortality pattern was observed for each tree species. Over all mortality of tree species was observed at each fire site. Maximum mortality of tree species (48.37%) was observed for *Quercus leucotricophora* and minimum mortality (0.001%) in case of *Pyrus pashia* and *Swida* sp. in Binsar Wildlife Sanctuary (Table 8.7).

In Daphiadhura, maximum mortality (38.95%) was observed for *Lyonia ovalifolia* and minimum (0.58%) for *Quercus floribunda* and *Cedrus deodara* (Table 8.8) while in Jageshwer mortality was maximum (32.07%) for *Rhododendron arboreum* and minimum (0.94%) for *Viburnum mullaha* (Table 8.9).

8.3.3 The Importance Value Index (IVI)

The total basal area occupied by a plant species in an area is considered as dominance. The maximum IVI (95.51) was accounted for by *Quercus leucotricophora* and considered as the most dominant tree species followed by *Rhododendron arboreum* (76.56) and *Lyonia ovalifolia* (41.17). The minimum IVI was calculated for *Euonymous* species (2.93) (Table 8.10). The IVI value was ranked in the ascending order of 1, 2, 3 and so on and the species possessing highest IVI value were ranked 1 followed by 2, 3 and so on according to the decreasing order of their IVI values. While at Daphiadhura (AWS) *Quercus lanuginosa* had the maximum IVI (120.3) followed by *Lyonia ovalifolia* (56.43) and *Rhododendron arboreum* (47.71), the minimum IVI (4.85) for *Myrica*

Table 8.7 Percent mortality between and within tree species in BWS.

Species	No. of dead trees	% Dead (between sp.)	No. of alive trees	%Mortality (within sp.)
Quercus leucotricophora	328	48.37	526	38.41
Quercus floribunda	8	1.17	16	33.34
Rhododendron arboreum	99	14.6	428	18.79
Lyonia ovalifolia	119	17.55	219	35.21
Euonymus sp.	0	0.00	1	0.00
Symplocos theifolia	0	0.00	1	0.00
Pyrus pashia	1	0.10	2	33.34
Toona serrata	0	0.00	1	0.00
Cedrus deodara	6	0.8	1	85.72
Pinus roxburghii	30	4.42	49	39.78
Alnus nepalensis	17	2.50	11	60.72
Viburnum mullaha	53	7.80	10	84.17
Myrica esculenta	3	0.44	7	30.00
Swida oblonga	13	1.99	4	76.48
Swida sp.	1	0.10	1	50.00

Table 8.8 Percent mortality between and within tree species in Daphiadhura.

Species	No. of Dead trees	% Dead (between sp.)	No. of alive trees	%Mortality (within sp.)
Quercus leucotricophora	2	1.16	0	100
Quercus floribunda	1	0.58	0	100
Quercus lanuginosa	23	13.37	99	18.85
Rhododendron arboreum	47	27.32	21	69.11
Lyonia ovalifolia	67	38.95	51	56.77
Toona serrata	1	0.58	0	100
Cedrus deodara	1	0.58	0	100
Alnus nepalensis	2	1.16	2	50
Myrica esculenta	0	0	1	0
Swida oblonga	25	14.53	13	65.78
Praxinus micrantha	3	1.74	0	100

Table 8.9 Percent mortality between and within tree species in Jageshwer.

Species	No. of dead trees	% Dead (between sp.)	No. of alive trees	%Mortality (within sp.)
Quercus leucotricophora	12	11.32	71	14.45
Rhododendron arboreum	34	32.07	53	39.08
Lyonia ovalifolia	30	28.3	12	72.42
Pyrus pashia	0	0	1	0
Pinus roxburghii	5	4.71	7	41.66
Viburnum mullaha	1	0.94	1	50
Myrica esculenta	24	22.64	4	85.7
Litsea umbrosa	0	0	1	0

Table 8.10 Importance value index and ranking of each tree species of Binsar Wildlife Sanctuary.

Species	IVI value	IVI rank
Quercus leucotricophora	95.51	1
Rhododendron arboreum	76.56	2
Lyonia ovalifolia	41.17	3
Pinus roxburghii	18.08	4
Viburnum mullaha	14.26	5
Alnus nepalensis	10.03	6
Quercus floribunda	8.58	7
Cedrus deodara	7.09	8
Swida oblonga	7.03	9
Myrica esculenta	6.07	10
Pyrus pashia	3.47	11
Swida sp.	3.23	12
Symplocos theifolia	2.98	13
Toona serrata	2.95	14
Euonymus sp.	2.93	15

Table 8.11 Importance value index and ranking of each tree species of Daphiadhura.

Species	IVI Value	IVI Rank
Quercus lanuginosa	120.3	1
Lyonia ovalifolia	56.43	2
Rhododendron arboreum	47.71	3
Swida oblonga	28.48	4
Alnus nepalensis	9.11	5
Quercus leucotricophora	8.52	6
Praxinus micrantha	8.08	7
Quercus floribunda	4.85	8
Toona serrata	4.85	8
Cedrus deodara	4.85	8
Myrica esculenta	4.85	8

esculenta, Quercus floribunda, Toona serrata and *Cedrus deodara* (Table 8.11). In Jageshwer, the maximum IVI was calculated for *Quercus leucotricophora* (90.6) followed by *Rhododendron arboreum* (89.02) and *Lyonia ovalifolia* (47.96). *Litsea umbrosa* had minimum IVI (5.51) (Table 8.12).

8.3.4 Effect of fire on different GBH classes of different tree species

In BWS maximum tree diversity (1.66) and richness (1.87) were found in GBH class 0-25 and 26-50 cm respectively while in Daphiadhura and Jageshwer, tree species diversity and richness were maximum in the GBH class 0-25 cm (Table 8.13). Two-way ANOVA showed significant difference between GBH classes of dead trees ($F = 33.85$, d.f = 5,20, $p < 0.01$) in BWS (Fig. 8.1). Significant difference was also observed in the dead trees of different tree species ($F = 5.28$, d.f. = 4,20, $p < 0.01$). To avoid limitations of the χ^2 contingency test, GBH class 101-200, 201-400 and >400 cm were merged in one class and the result showed significant difference in the different GBH class of dead tree ($\Sigma \chi^2 = 292.89$, d.f = 3, $p < 0.001$) and the highest mortality was found in the GBH class 0-25 cm and least mortality was observed in the merged GBH class (>101 cm).

In Daphiadhura GBH class 201-400 & >400 cm were merged to pin point the exact affected class. The result showed that class >201 cm was least affected while 26-50 cm class was most affected ($\Sigma \chi^2 = 65.15$, d.f. = 4, $p < 0.001$) (Fig. 8.3). In Jageshwer, GBH class 101-200 & 201-400 cm were merged and the result showed that survival was highest in class >101 cm ($\Sigma\chi^2 = 78.71$, d.f = 3, $p < 0.001$) (Fig. 8.5). GBH class 51-100, 101-200, 201-400 and >400 cm of top five IVI ranking tree species were merged to follow the

Table 8.12 Importance value index and ranking of each tree species at Jageshwer.

Species	IVI Value	IVI Rank
Quercus leucotricophora	90.6	1
Rhododendron arboreum	89.02	2
Lyonia ovalifolia	47.96	3
Myrica esculenta	32.32	4
Pinus roxburghii	21.11	5
Viburnum mullaha	7.64	6
Pyrus pashia	5.83	7
Litsea umbrosa	5.51	8

assumption of the statistical test. χ^2 contingency test result showed maximum mortality was found in 0-26 cm GBH class for *Viburnum mullaha* and least mortality was found in > 51 cm for *Lyonia ovalifolia* in BWS. In Daphiadhura the result was not significant for top five IVI ranking tree species ($\Sigma\chi^2 = 6.74$, d.f.= 6, $p > 0.05$) while test could not be performed for Jageshwer.

8.3.5 Effect of fire on height categories of different tree species

Maximum tree diversity in the burnt patches was observed in the fire height category between 401-800 cm in BWS, Jageshwer and Daphiadhura, while maximum tree species richness at these places was observed in 801-1600 cm, 201-400 and 401-800 cm categories respectively (Table 8.14). Two-way ANOVA showed significant difference between different fire height categories in dead trees ($F = 4.3$, d.f = 7, 28, $p < 0.01$) in BWS (Fig. 8.2). The mortality rate also differed significantly among tree species ($F = 4.82$, d.f.= 4,28, $p < 0.01$). Height categories 0-50, 51-100 and 101-200 cm were merged into single category and 801-1600, 1601-3200 and >3200 cm were merged in another category to overcome the limitations of the statistical test. Maximum mortality was found in >801 cm fire height category and least was found in <200 cm category. In Daphiadhura the category 801-1600 cm was most affected (Fig. 8.4) while in Jageshwer categories 0-50 cm and 51-100 cm were merged in single class and categories 801-1600 & 1601-3200 cm were merged and the test between them showed that the category >801 cm was most affected (Fig. 8.6).

In BWS, height categories 0-50, 51-100, 101-200 & 201-400 and 801-1600, 1601-3200 & >3200 cm of top four IVI ranking tree species were merged to get two

Table 8.13 Tree species diversity and richness in different GBH classes at Binsar, Jageshwer and Daphiadhura after the fire in postmonsoon 96.

GBH classes	1	2	3	4	5	6
Binsar						
Diversity	1.66	1.41	1.36	1.23	1.13	0
Richness	1.45	1.87	1.55	1.66	1.31	0
Jageshwer						
Diversity	1.59	1.51	1.4	1.05	0.64	0
Richness	1.3	1.15	1.13	0.78	0.91	0
Daphiadhura						
Diversity	1.49	1.48	1.39	1.11	0.55	0
Richness	1.59	1.1	1.3	1.26	0.59	0

GBH class (in cm) 1= 0-25, 2 = 26-50, 3 = 51-100, 4 = 101-200, 5 = 201-400, 6 = >400

Table 8.14 Tree species diversity and richness in different height categories at Binsar, Jageshwer and Daphiadhura after the fire in postmonsoon 96.

Fire height categories	1	2	3	4	5	6	7	8
Binsar								
Diversity	1.32	1.32	1.28	1.41	1.57	1.27	0.98	0
Richness	1.26	1.1	1.35	1.62	1.78	1.84	0.72	1.44
Jageshwer								
Diversity	0.59	0.64	1.52	1.26	1.43	1.39	0.64	0
Richness	0.73	0.91	1.44	1.55	1.41	0.97	0.91	0
Daphiadhura								
Diversity	0	0	0	0	1.45	1.36	0	0
Richness	0	0	0	0	1.63	1.5	0	0

Fire height categories (in cm) 1= 0-50, 2 = 51-100, 3 = 101-200, 4 = 201-400, 5 = 401-800, 6 = 801-1600, 7 = 1601-3200 and 8 = >3200

Fig. 8.1 Number of dead trees in different GBH class in Binsar Wildlife Sanctuary.

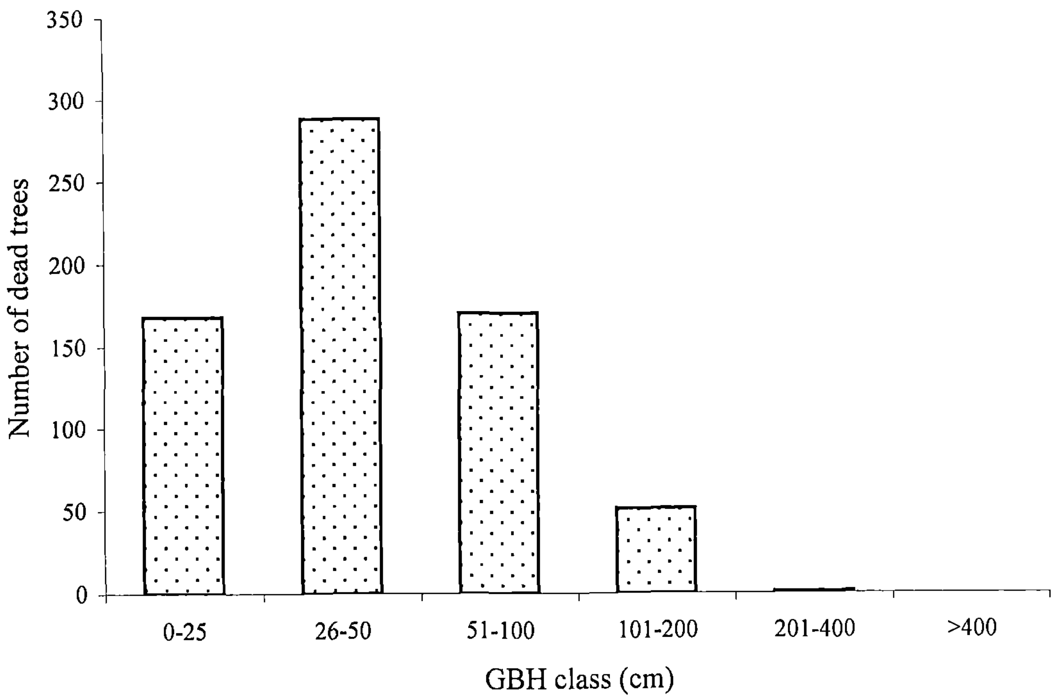


Fig. 8.2 Number of dead trees in different height categories in Binsar Wildlife Sanctuary.

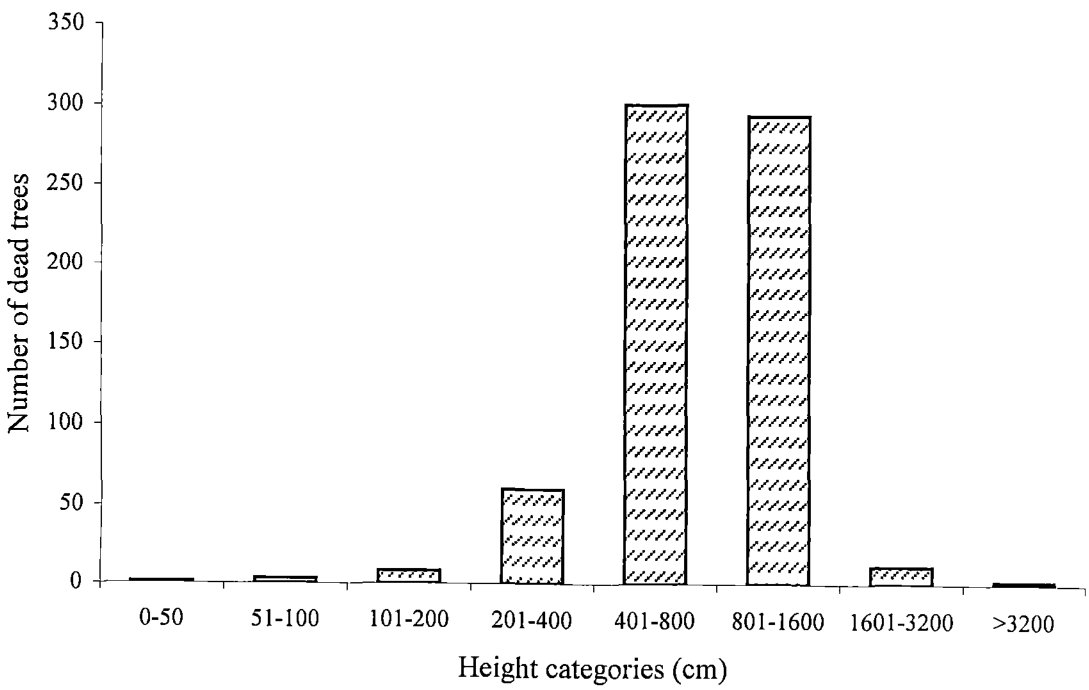


Fig. 8.3 Number of dead trees in different GBH class in Daphiadhura.

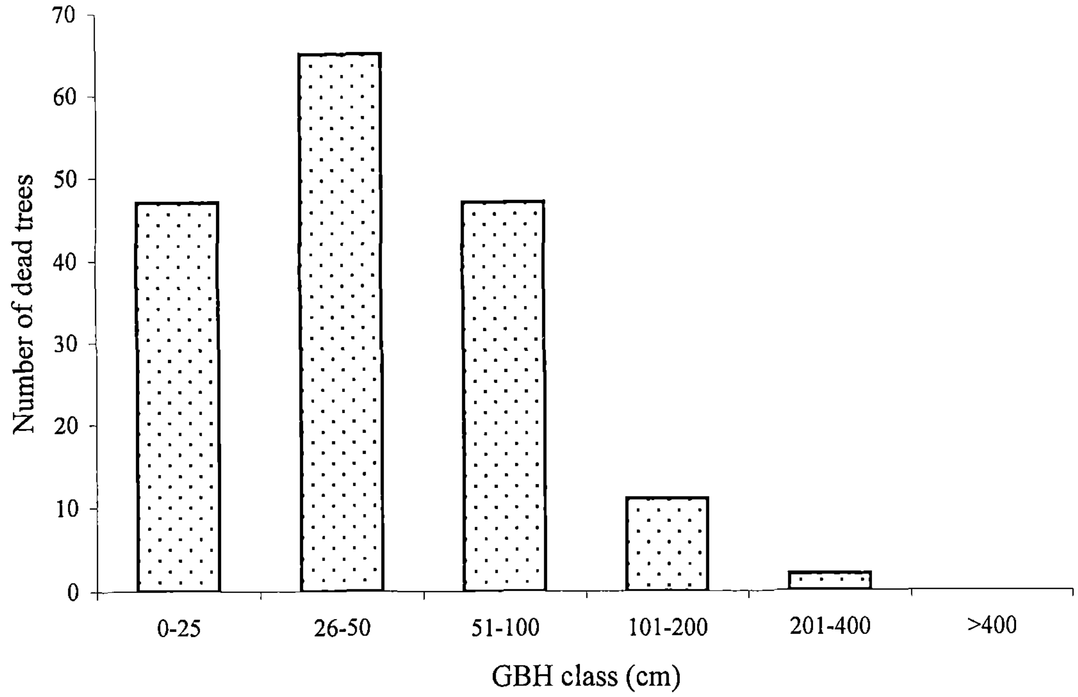


Fig. 8.4 Number of dead trees in different height categories in Daphiadhura.

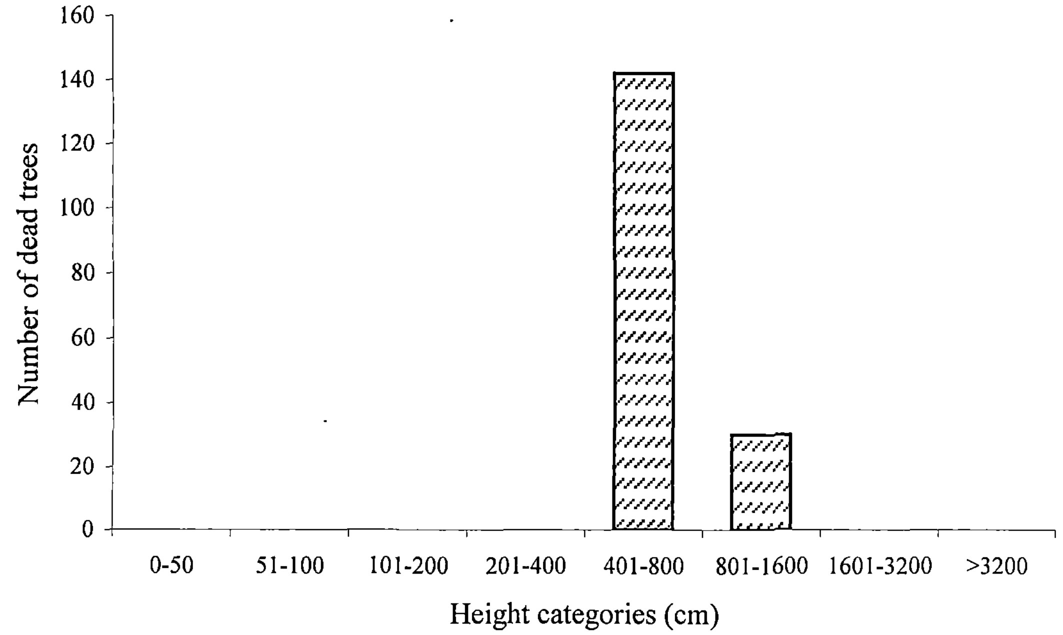


Fig. 8.5 Number of dead trees in different GBH class in Jageshwer.

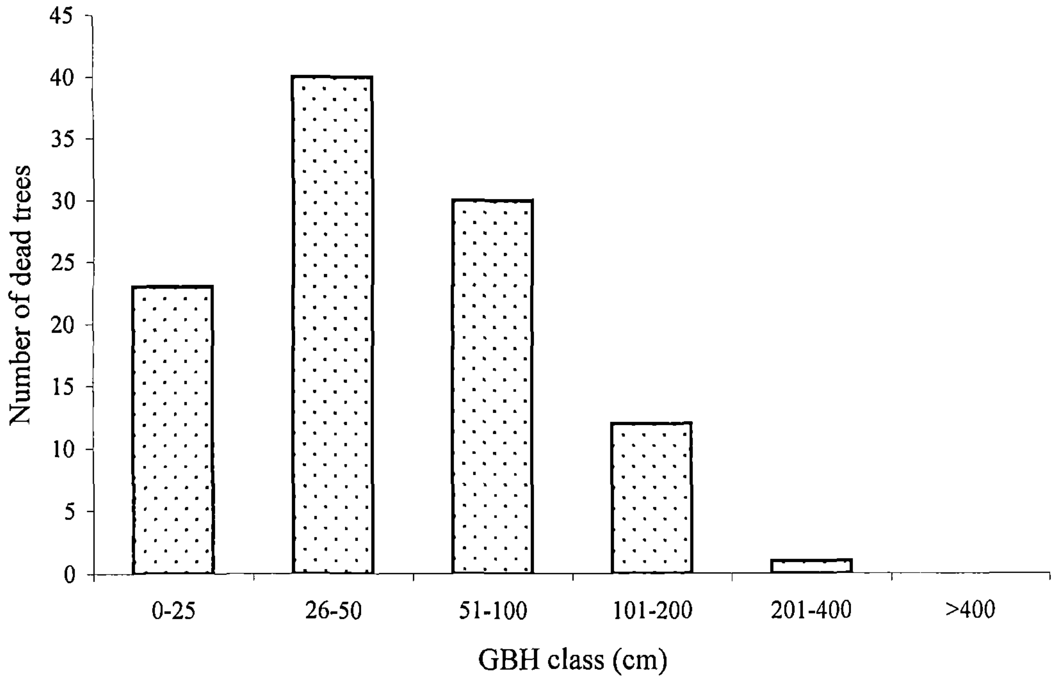
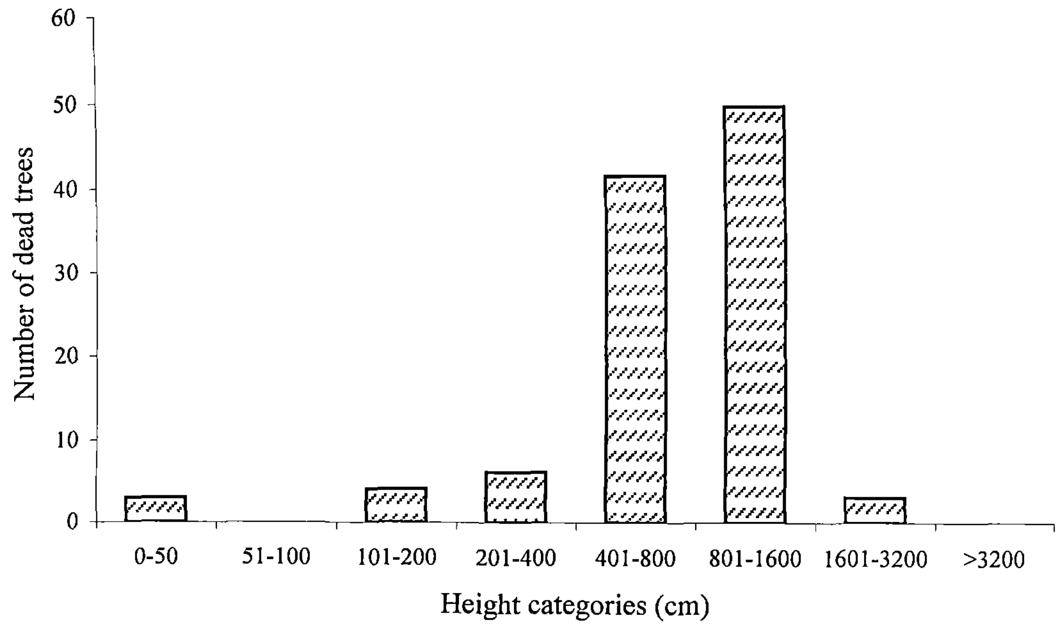


Fig. 8.6 Number of dead trees in different height categories in Jageshwer.



separate categories to avoid the statistical limitations. Significant difference ($\Sigma\chi^2 = 83.03$, d.f. = 6, $p < 0.001$) was observed in the mortality of different height categories of different tree species and *Viburnum mullaha* falling under the fire height category 401-800 cm was most affected and category > 800 cm was least affected in the same species. Test for Jageshwer and Daphiadhura could not be performed due to limitation in data set.

In BWS mortality of *Rhododendron arboreum* (18.79%), *Euonymous* species (0%), *Symplocos theifolia* (0%) and *Toona serrata* (0%) was significantly less than expected according to availability (Table 8.15) while other species had significantly higher mortality than expected.

Quercus lanuginosa (18.85%) in Daphiadhura, *Pyrus pashia* (0%) and *Litsea umbrosa* (0%) in Jageshwer had significantly less mortality than expected according to availability (Tables 8.16 & 8.17). But *Lyonia ovalifolia* (72.42%) in Jageshwer had significantly more mortality than expected.

8.3.6 Regeneration

A total of 18 regenerating (seedlings) tree species were encountered after the fire of premonsoon 1995 in BWS. Maximum regeneration was accounted for by *Swida oblonga* (31.14%) followed by *Quercus leucotricophora* (25.75%) and *Lyonia ovalifolia* (9.98%), and minimum regeneration (0.2%) was recorded for *Persea duthiei*, *Praxinus micrantha* and *Phoenix humilis* (Table 8.18). Maximum density (1022.3 / ha ± 988.19) was calculated for *Quercus leucotricophora* and minimum density (353.86 / ha ± 0) for *Persea duthiei, Praxinus micrantha, Phoenix humilis* (Table 8.18). A total of nine and 12 regenerating (seedlings) tree species were found in Jageshwer and Daphiadhura

Table 8.15 Proportion available (Pi), Proportion dead ($\bar{P}i$), Bonferroni confidence interval and significant mortality of each tree species at BWS (0 = in proportion to availability, - = less mortality in proportion to availability).

Tree species	Pi	$\bar{P}i$	Bonferroni C.I.	Significant mortality
Quercus leucotricophora	0.436	0.483	$0.428 \leq p_1 \leq 0.539$	0
Quercus floribunda	0.012	0.012	$-0.0002 \leq p_2 \leq 0.024$	0
Rhododendron arboreum	0.269	0.146	$0.107 \leq p_3 \leq 0.185$	-
Lyonia ovalifolia	0.173	0.175	$0.03 \leq p_4 \leq 0.19$	0
Euonymus sp.	0.0005	0	$0 \leq p_5 \leq 0$	-
Symplocos theifolia	0.0005	0	$0 \leq p_6 \leq 0$	-
Pyrus pashia	0.001	0.001	$-0.205 \leq p_7 \leq 0.207$	0
Toona serrata	0.0005	0	$0 \leq p_8 \leq 0$	-
Cedrus deodara	0.003	0.008	$-0.001 \leq p_9 \leq 0.017$	0
Pinus roxburghii	0.040	0.044	$0.022 \leq p_{10} \leq 0.66$	0
Alnus nepalensis	0.014	0.025	$0.02 \leq p_{11} \leq 0.029$	0
Viburnum mullaha	0.032	0.078	$0.048 \leq p_{12} \leq 0.108$	0
Myrica esculenta	0.005	0.004	$-0.003 \leq p_{13} \leq 0.012$	0
Swida oblonga	0.008	0.019	$0.004 \leq p_{14} \leq 0.035$	0
Swida sp.	0.001	0.001	$-0.003 \leq p_{15} \leq 0.005$	0

Table 8.16 Proportion available (Pi), proportion dead ($\bar{P}i$), Bonferroni confidence interval and significant mortality of each tree species at Daphiadhura (0 = in proportion to availability, - = less mortality in proportion to availability).

Tree species	Pi	$\bar{P}$i	Bonferroni C.I.	Significant mortality
Quercus leucotricophora	0.005	0.012	$-0.113 \leq p_1 \leq 0.035$	0
Quercus floribunda	0.003	0.006	$-0.01 \leq p_2 \leq 0.022$	0
Quercus lanuginosa	0.339	0.133	$-0.06 \leq p_3 \leq 0.206$	-
Rhododendron arboreum	0.189	0.273	$0.178 \leq p_4 \leq 0.368$	0
Lyonia ovalifolia	0.328	0.389	$0.285 \leq p_5 \leq 0.493$	0
Toona serrata	0.003	0.006	$0.01 \leq p_6 \leq 0.022$	0
Cedrus deodara	0.003	0.006	$0.01 \leq p_7 \leq 0.022$	0
Alnus nepalensis	0.011	0.012	$-0.113 \leq p_8 \leq 0.035$	0
Myrica esculenta	0.003	0	$0 \leq p_9 \leq 0$	-
Swida oblonga	0.106	0.145	$0.07 \leq p_{10} \leq 0.221$	0
Praxinus micrantha	0.008	0.017	$-0.01 \leq p_{11} \leq 0.045$	0

Table 8.17 Proportion available (Pi), Proportion dead ($\bar{P}i$), Bonferroni confidence interval and significant mortality of each tree species at Jageshwer (0 = in proportion to availability, - = less mortality in proportion to availability, + = more mortality in proportion to availability).

Tree species	Pi	$\bar{P}i$	Bonferroni C.I.	Significant mortality
Quercus leucotricophora	0.324	0.113	$0.03 \leq p_1 \leq 0.196$	0
Rhododendron arboreum	0.339	0.321	$0.198 \leq p_2 \leq 0.443$	0
Lyonia ovalifolia	0.164	0.283	$0.169 \leq p_3 \leq 0.405$	+
Pyrus pashia	0.003	0	$0 \leq p_4 \leq 0$	-
Pinus roxburghii	0.046	0.047	$-0.008 \leq p_5 \leq 0.103$	0
Viburnum mullaha	0.008	0.009	$-0.015 \leq p_6 \leq 0.034$	0
Myrica esculenta	0.109	0.226	$0.12 \leq p_7 \leq 0.336$	0
Litsea umbrosa	0.003	0	$0 \leq p_8 \leq 0$	-

respectively. Maximum regeneration was observed for *Quercus leucotricophora* (43.75%) at Jageshwer while *Quercus lanuginosa* (42.02%) at Daphiadhura. Minimum regeneration was observed for *Litsea umbrosa* (0.89%) at Jageshwer while *Pyrus pashia* (0.36%) and *Lindera pulcherrima* (0.36%) at Daphiadhura in Askot Wildlife Sanctuary. Maximum density of seedlings was found for *Pyrus pashia* (5307.85 / ha ± 0) at Jageshwer while *Toona serrata* (5307.85 / ha ± 0) at Daphiadhura.

11 tree species at sapling stage were recorded from Binsar. The maximum density was accounted for by *Swida oblonga* (325.54 / ha ± 533.88). Maximum mortality was found in *Lyonia ovalifolia* (64.29%) and mortality was observed in *Quercus floribunda*, *Euonymous* sp., *Pyrus pashia*, *Alnus nepalensis*, *Myrica esculenta* and *Lindera pulcherrima*. A total of eight and nine tree species (saplings) were recorded from Jageshwer and Daphiadhura respectively. Maximum density was calculated for *Rhododendron arboreum* (424.63 / ha ± 813.78) and *Lyonia ovalifolia* (424.63 / ha ± 760.76) at Jageshwer. Maximum mortality at Jageshwer was recorded for *Rhododendron arboreum* (60%). Maximum sapling density at Daphiadhura was recorded for *Lyonia ovalifolia* (1220.81 / ha ± 1629.58.) and maximum mortality was also observed for the same species (26.31%). Minimum mortality was recorded for *Pyrus pashia* (0.58%) (Table 8.19).

8.3.7 Mean threat score for sites

The generated mean threat score for various surveyed sites varied from 0.78 to 2.3. On this basis, the sites Jilling and Sunderdunga have fallen under low threats (0-1 mean threat score) while Binsar Wildlife Sanctuary, Sitlakhet, Jageshwer, Pindari,

Table 8.18. %Seedling (SD) and density of different tree species at the burnt sites during 1996-97 in Kumaon.

	Binsar		Jageshwer		Daphiadhura	
Species	SD	% regeneration	SD	% regeneration	SD	% regeneration
Quercus leucotricophora	773 ± 555	25.75	1926 ± 710	43.75	-	-
Quercus floribunda	471± 204	0.79	-	-	-	-
Quercus lanuginosa	-	-	-	-	2280 ± 1127	42.01
Rhododendron arboreum	655 ± 424	9.98	1011 ± 476	17.85	825 ± 608	12.68
Lyonia ovalifolia	676 ± 463	8.78	619 ± 338	6.2	898 ± 470	11.95
Persia duthiei	353 ± 0	0.2	-	-	-	-
Euonymus tingens	707 ± 288	1.59	-	-	-	-
Euonymus sp.	884 ± 204	1.99	1061 ± 0	2.67	-	-
Pyrus pashia	579 ± 455	3.59	5307 ± 0	13.39	353 ± 0	0.36
Toona serrata	530 ± 250	0.59	-	-	5307 ± 0	5.43
Pinus roxburghii	884 ± 895	7.98	-	-	353 ± 0	0.72

Alnus nepalensis	566 ± 193	1.59	-	-	530 ± 250	1.08
Viburnum mullaha	412 ± 144	1.39	442 ± 176	4.46	-	-
Myrica esculenta	393 ± 117	1.99	471 ± 204	3.57	884 ± 250	1.81
Swida oblonga	1022 ± 988	31.14	707 ± 408	7.14	1194 ± 546	19.56
Meliosoma dillenaeafolia	-	-	-	-	1415 ± 0	1.44
Litsea umbrosa	-	-	353 ± 0	0.89	-	-
Lindera pulcherrima	636 ± 296	1.79	-	-	353 ± 0	0.36
Praxinus micrantha	353 ± 0	0.2	-	-	825 ± 204	2.53
Benthamidia capitata	353 ± 0	0.2	-	-	-	-
Albezzia lebback	707 ± 0	0.39	-	-	-	-

Table 8.19 Sapling density (SAD) and % dead of different tree species at the burnt sites during 1996-97 in Kumaon.

Species	Binsar		Jageshwer		Daphiadhura	
	SAD	% dead	SAD	% dead	SAD	% dead
Quercus leucotricophora	49 ± 261	49.29	176 ± 382	0	-	-
Quercus floribunda	14 ± 111	0	-	-	-	-
Quercus lanuginosa	-	-	-	-	601 ± 629	19.29
Rhododendron arboreum	17.69 ± 116.6	4.76	424 ± 813	60	920 ± 1156	21.63
Lyonia ovalifolia	233 ± 562	64.29	424 ± 760	0	1220 ± 1629	26.31
Euonymus sp.	3 ± 35	0	128 ± 426	20	-	-
Pyrus pashia	3 ± 35	0	64 ± 213	0	17 ± 79	0.58
Cedrus deodara	-	-	-	-	53 ± 173	1.75
Alnus nepalensis	7 ± 70	0	-	-	488 ± 943	1.16
Viburnum mullaha	24 ± 135	4.76	128 ± 426	20	-	-

Myrica esculenta	7 ± 49	0	-	-	438 ± 886	2.92
Swida oblonga	325 ± 533	11.9	326 ± 106	0	573 ± 1051	25.14
Litsea umbrosa	-	-	74 ± 141	0	-	-
Lindera pulcherrima	7 ± 70	0	-	-	-	-
Praxinus micrantha	-	-	-	-	530 ± 1006	1.75

Gandhura (AWS) and Munsiary under high threats (>2 mean threat score) and rest of the sites have fallen in medium threat category (1.1-2 mean threat score) (Table 8.20). Highest mean threat score (2.3) was recorded for Jageshwer and minimum mean threat score (0.78) was recorded for Sunderdunga reserve forest. Similar results were also obtained on the basis of threat index by single linkage cluster analysis and Jilling and Sunderdunga formed one cluster while Binsar, Sitlakhet, Jageshwer, Maheshkhan, Vinaiyak and Daphiadhura (AWS) formed separate cluster (Fig. 8.7).

Results for the similarity in the presence/absence of different threats at various sites (Fig. 8.8) showed slightly different pattern from single linkage cluster analysis obtained on the basis of mean threat score. Jilling and Sunderdunga experienced similar kind of threats like no tree cutting, lopping, grazing, forest fire and bark extraction was observed at both the sites. Binsar Wildlife Sanctuary, Gager, Sitlakhet, Mukteshwer, Mechh, Duku (AWS) and Wachham experienced tree cutting, lopping, grazing, grass harvesting, fuel wood collection and poaching and wild animal product trade but no bark extraction was found at these places. No tapping, medicinal plant extraction, tourism and construction work was observed at Daphiadhura and Majtham in Askot Wildlife Sanctuary.

Statistical results showed that the relationship between fuel consumption with each dependent factor except livestock population was significant. The regression coefficient of fuel wood collection was highly related with human population, land area available for different purposes and source of income through different means. The factors human population and source of income together accounted for 68.6% of variation in fuel wood collection ($F = 21.86$, $p < 0.001$). The regression of fuel wood collection with land area available was significant ($F = 12.42$, $p < 0.002$) with regression coefficients and also accounted for 37.2% variation (Table 8.21).

8.3.8 Conservation assessment of pheasant species as well as localities

The correlation between different attributes showed significant results. The altitude range was significantly negatively correlated with degree of disturbance ($r_s = -0.918$, $p < 0.02$). The species, which occupied wide altitude range, faced less disturbance as compared to narrow altitude range occupying species. The degree of disturbance was also positively correlated with legal status of forest patch ($r_s = 0.947$, $p < 0.01$). The degree of endangerment of species was positively correlated with the distribution range of the species ($r_s = 0.975$, $p < 0.005$). Vulnerable and endangered species as well as those species occupying narrow distribution range in the Kumaon Himalaya were given more weightage. So, the Cheer, Satyr and Himalayan Monal had occupied higher rank in both the attributes.

Table 8.22 provides the conservation value of different pheasant species of Kumaon. The Satyr Tragopan was the highest ranked species followed by the Himalayan Monal and Cheer pheasant while Whitecrested Kalij and Koklass obtained least conservation status. None of the pheasant species were found in the category 'substantial portion of the global range in the Himalayas'.

Table 8.23 provides conservation status of different sites, which was based on the combined conservation values of pheasant species present therein. The maximum conservation status was obtained for Pindari (3.76), followed by Wachham (3.16), Sunderdunga (2.55), Munsiary (2.55) and Vinaiyak (2.23). All the five species were

Table 8.20 Mean Threat Scores and Ranking of sites.

Sites	Mean Threat score	Rank
Jageshwer	2.3	3
Binsar WLS	2.17	3
Munsiary	2.13	3
Sitlakhet	2.04	3
Pindari	2.04	3
Gandhura	2.04	3
Dhakuri	2.00	2
Kunjakharak	1.91	2
Wachham	1.91	2
Vinaiyak	1.87	2
Gager	1.87	2
Mukteshwer	1.83	2
Gasi	1.83	2
Mechh	1.83	2
Sobala	1.78	2
Maheshkhan	1.65	2
Kilbery	1.61	2
Daphiadhura	1.61	2
Majtham	1.52	2
Pandavkholi	1.48	2
Duku	1.39	2
Jilling	1.00	1
Sunderdunga	0.78	1

Table 8.21 Stepwise multiple regression on fuel wood collection with different disturbance factors as dependent variables.

Model	V	MR	R^2	C	F value	Significance level
1	Human population	0.74	0.55	+	26.11	0.00
2	Source of income	0.83	0.69	+	21.85	0.00
3	Land area available	0.61	0.37	+	12.42	0.002

V = Variables, MR = Multiple regression, R^2 = Coefficient of determination, C = Correlation, F = F values.

Table 8.22 Combined conservation status value (CCSV) for different pheasant in Kumaon Himalaya.

Species	CCSV
Whitecrested Kalij (*Lophura leucomelana*)	0.484
Koklass (*Pucrasia macrolopha*)	0.664
Cheer (*Catreus wallichii*)	0.75
Himalayan Monal (*Lophophorus impejanus*)	0.93
Satyr Tragopan (*Tragopan satyra*)	0.958

Table 8.23 Conservation value of different surveyed sites on the basis of pheasant species composition.

Sites	District	Conservation value (CV)
Pindari	Bageshwer	3.766
Wachham	Bageshwer	3.16
Sunderdunga	Bageshwer	2.552
Munsiary	Pithoragarh	2.552
Vinaiyak	Naini Tal	2.23
Sobala	Pithoragarh	1.414
Kunjakhrarak	Naini Tal	1.148
Maheshkhan	Naini Tal	1.148
Gager	Naini Tal	1.148
Mukteshwar	Naini Tal	1.148
Binsar	Bageshwer	1.148
Pandavkholi	Almora	1.148
Daphiadhura	Pithoragarh	1.148
Majtham	Pithoragarh	1.148
Gandhura	Pithoragarh	1.148
Duku	Pithoragarh	1.148
Kilbery	Naini Tal	0.664
Jageshwer	Almora	0.664
Dhakuri	Bageshwer	0.664
Mechh	Champawat	0.664
Jilling	Naini Tal	0.484
Sitlakhet	Almora	0
Gasi	Bageshwer	0

```
                         Rescaled Distance Cluster Combine

                   0         5        10        15        20        25
SITES        Num   +---------+---------+---------+---------+---------+


GASI          12   -+
MECHH         23   -+
MUKTESHWER     6   -+
SOBALA        20   -+-+
KUNJAKHARAK    3   -+ I
WACHHAM       14   -+ I
VINAIYAK       2   -+ +-+
GAGER          5   -+ I I
PINDARI       16   -+ I I
MUNSIARY      22   -+ I I
BINSAR         8   -+-+ I
SITLAKHET     10   -+   I
GANDHURA      19   -+   I
DHAKURI       13   -+   I
KILBERY        1   -+   I
DAPHIADHURA   17   -+-+ +-------------------------------------------+
MAHESHKHAN     4   -+ +-+                                           I
PANDAVKHOLI    9   -+-+ I                                           I
MAJTHAM       18   -+ I I                                           I
DUKU          21   ---+ I                                           I
JAGESHWER     11   -----+                                           I
JILLING        7   ---------------+---------------------------------+
SUNDERDUNGA   15   ---------------+
```

Fig. 8.7 Dendrogram of different sites on the basis of threat index using Single Linkage.

```
                                   Rescaled Distance Cluster Combine

                            0         5        10        15        20        25
Sites              Num      +---------+---------+---------+---------+---------

DAPHIADHURA         17      -+---+
MAJTHAM             18      -+   I
GANDHURA            19      -----+-----+
KUNJAKHARAK          3      -----+     I
SOBALA              20      -----------+
VINAIYAK             2      -----------+
DHAKURI             13      -+---------+
PINDARI             16      -+         I
JAGESHWER           11      -----+-----+
MUNSIARY            22      -----+     I
GASI                12      -----+-----+
WACHHAM             14      -----+     +---------------+
DUKU                21      -----+     I               I
MECHH               23      -----+     I               I
MUKTESHWER           6      -----+     I               I
SITLAKHET           10      -----+-----+               I
GAGER                5      -----+     I               +---------------------+
BINSAR               8      -----+     I               I                     I
PANDAVKHOLI          9      -----------+               I                     I
MAHESHKHAN           4      -----------+               I                     I
KILBERY              1      -----------+               I                     I
JILLING              7      ---------------------------+                     I
SUNDERDUNGA         15      -------------------------------------------------+
```

Fig. 8.8 Dendrogram of presence/absence of threats using Single Linkage.

found in Pindari while the presence of Cheer pheasant at Wachham and Vinaiyak upgraded the conservation status of these sites. The localities such as Sitlakhet and Gasi had nil conservation status in terms of pheasants. Kilbery and Kunjakharak also had low conservation status by having Kalij and Koklass.

8.3.9 Spatial relationship

There was no significant relationship between pheasant species composition and threat index. Map showed that only Pindari had maximum pheasant species in spite of being a high threat area while Binsar, Munsiary and Gandhura had medium species composition. Sunderdunga and Jilling had fallen under low threat category and also had medium pheasant species composition (Fig. 8.9).

Except Dhakuri, Sunderdunga, Pandavkholi, Maheshkhan, Jilling, and Sobala rest of the patches experienced high threats in terms of sets of threat parameters (cutting, lopping, grazing, grass harvesting, human & livestock population and surveyed forest patch size) experienced by each surveyed forest patch. The map showed that only Binsar had high Kalij abundance (Fig. 8.10) and Vinaiyak, Mukteshwer and Sobala had low Koklass abundance though all these sites were categorized as high threat areas while Koklass abundance was found be medium at low threat area in Sunderdunga only (Fig. 8.11). No significant relation was found in Cheer abundance and threat layers. Cheer was found only in Wachham and Vinaiyak area. In Vinaiyak, threats were high and Cheer abundance was medium while threats were medium with high Cheer abundance in Wachham (Fig. 8.12). Munsiary and Pindari experienced high threats with high Monal abundance while Sunderdunga had low threats with medium Monal abundance (8.13). On

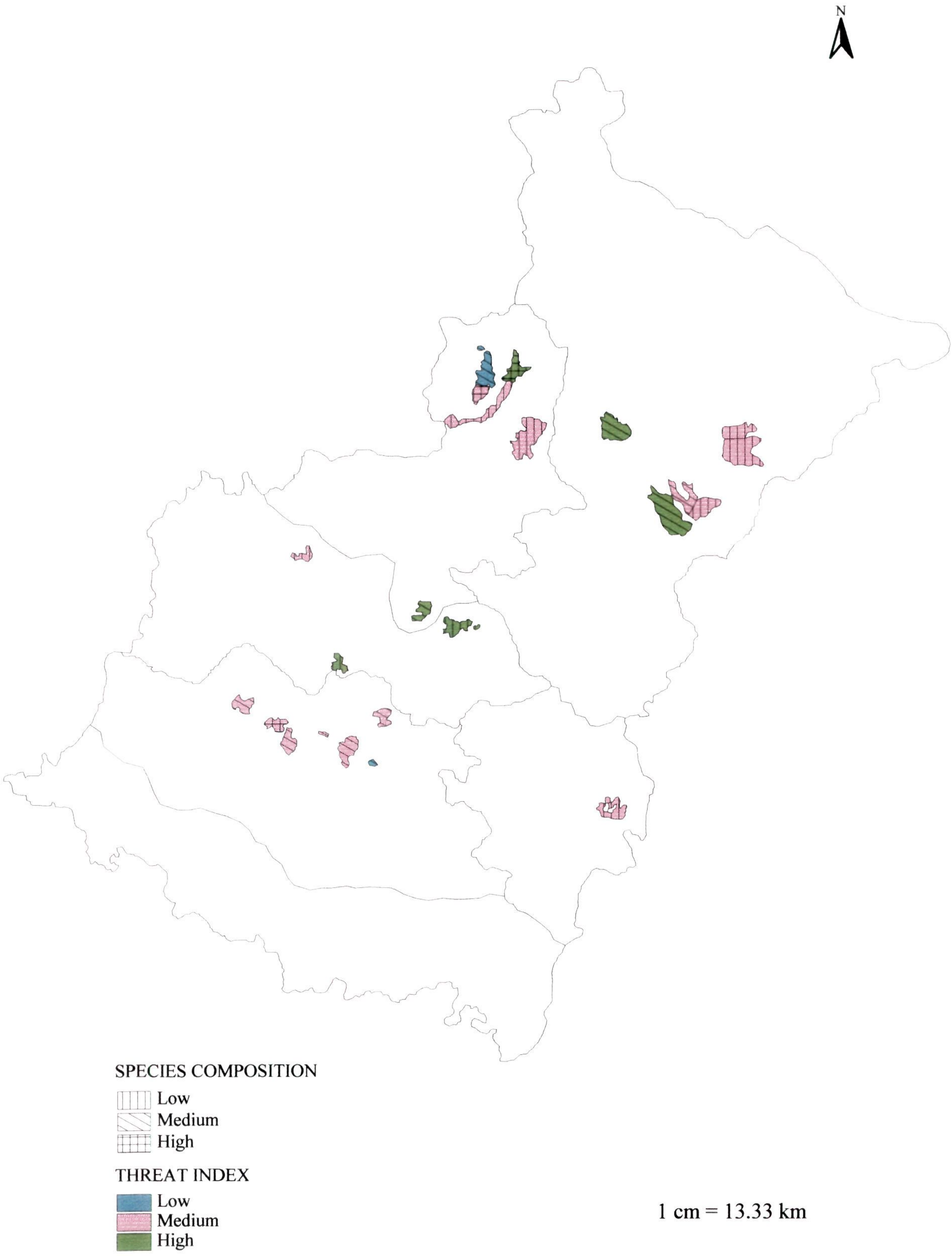


Fig. 8.9 Pheasant species composition in relation to threat index in Kumaon Himalaya.

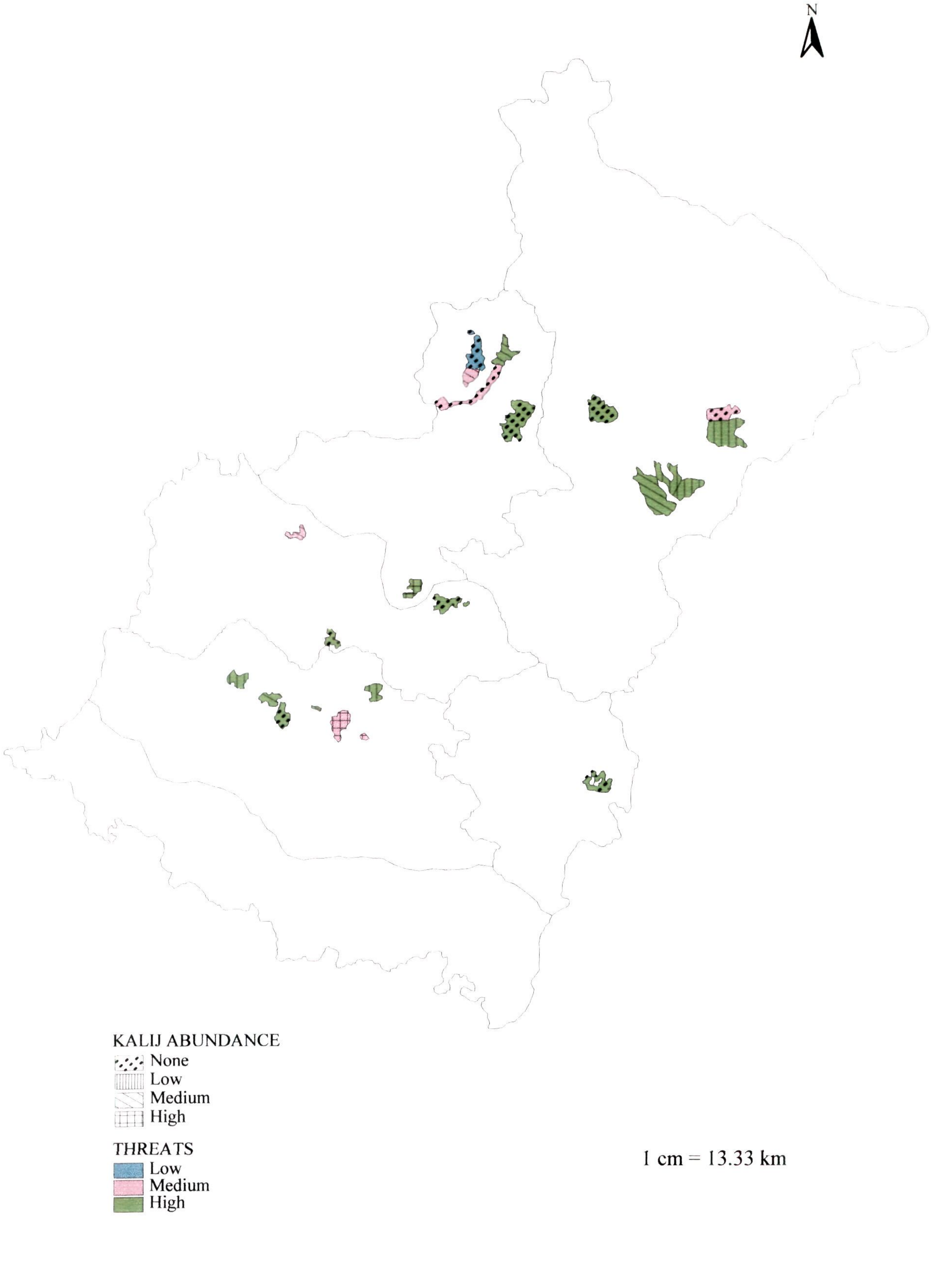


Fig. 8.10 Kalij abundance in relation to threats in Kumaon Himalaya.

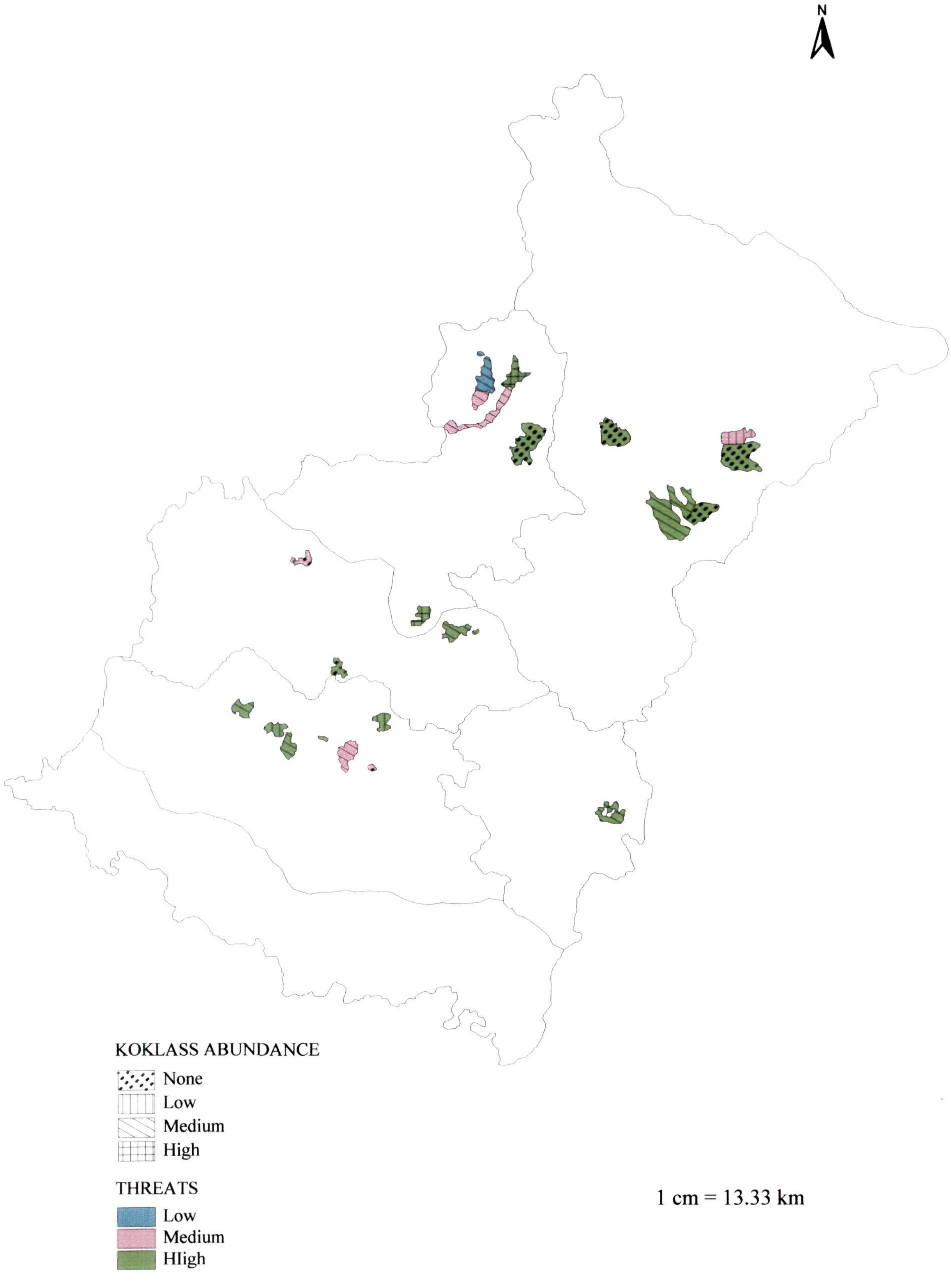


Fig. 8.11 Koklass abundance in relation to threats in Kumaon Himalaya.

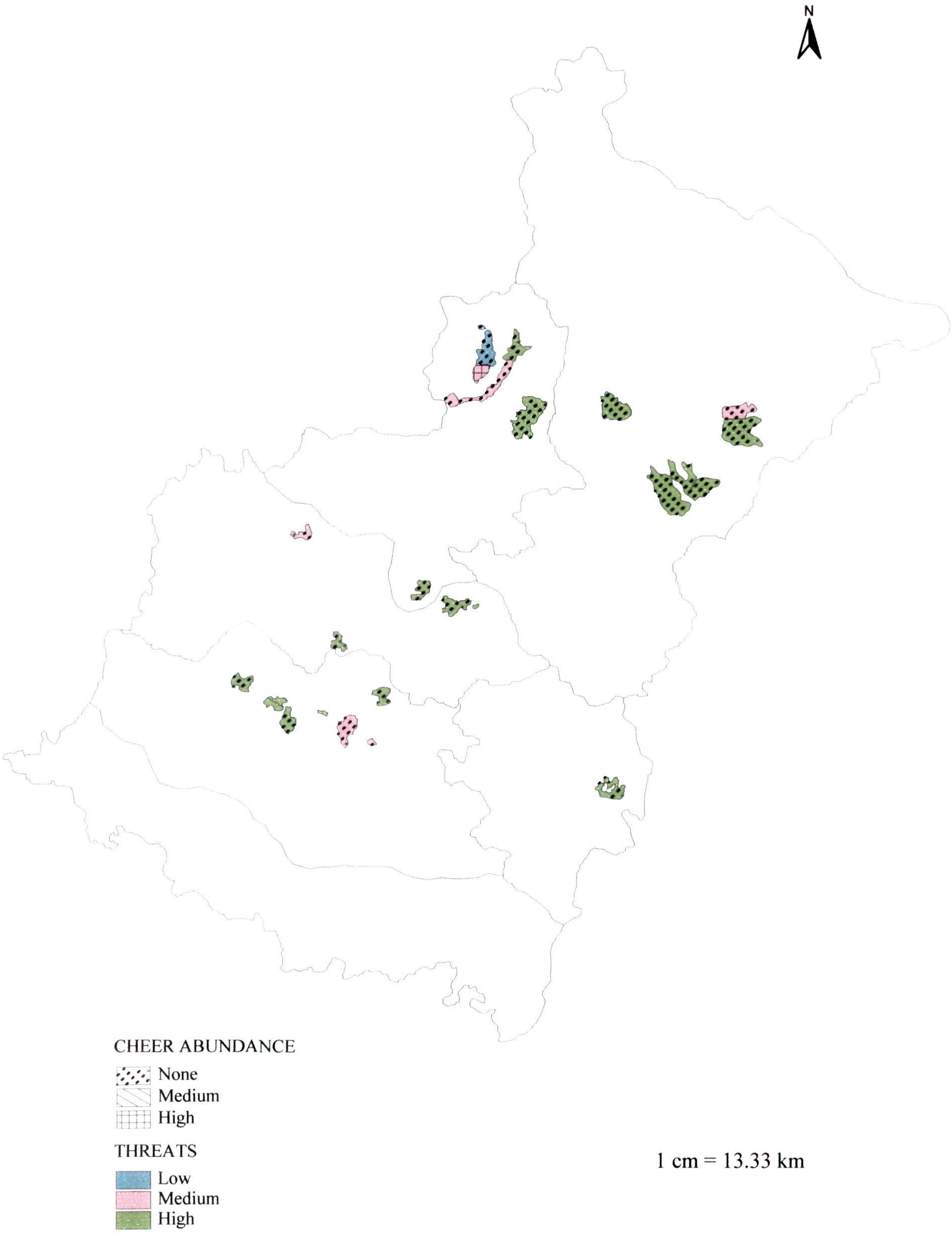


Fig. 8.12 Cheer pheasant abundance in relation to threats in Kumaon Himalaya.

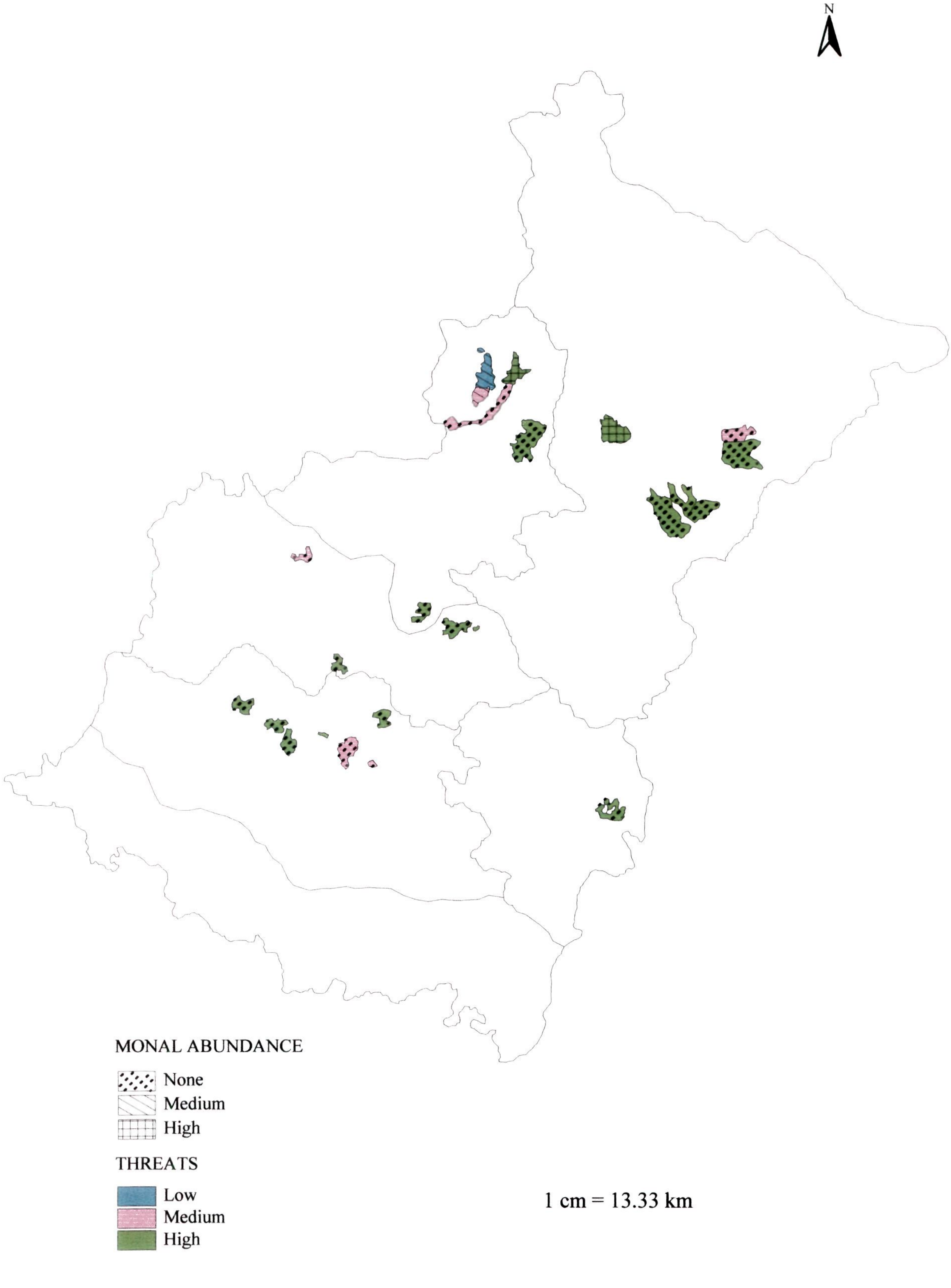


Fig. 8.13 Monal abundance in relation to threats in Kumaon Himalaya.

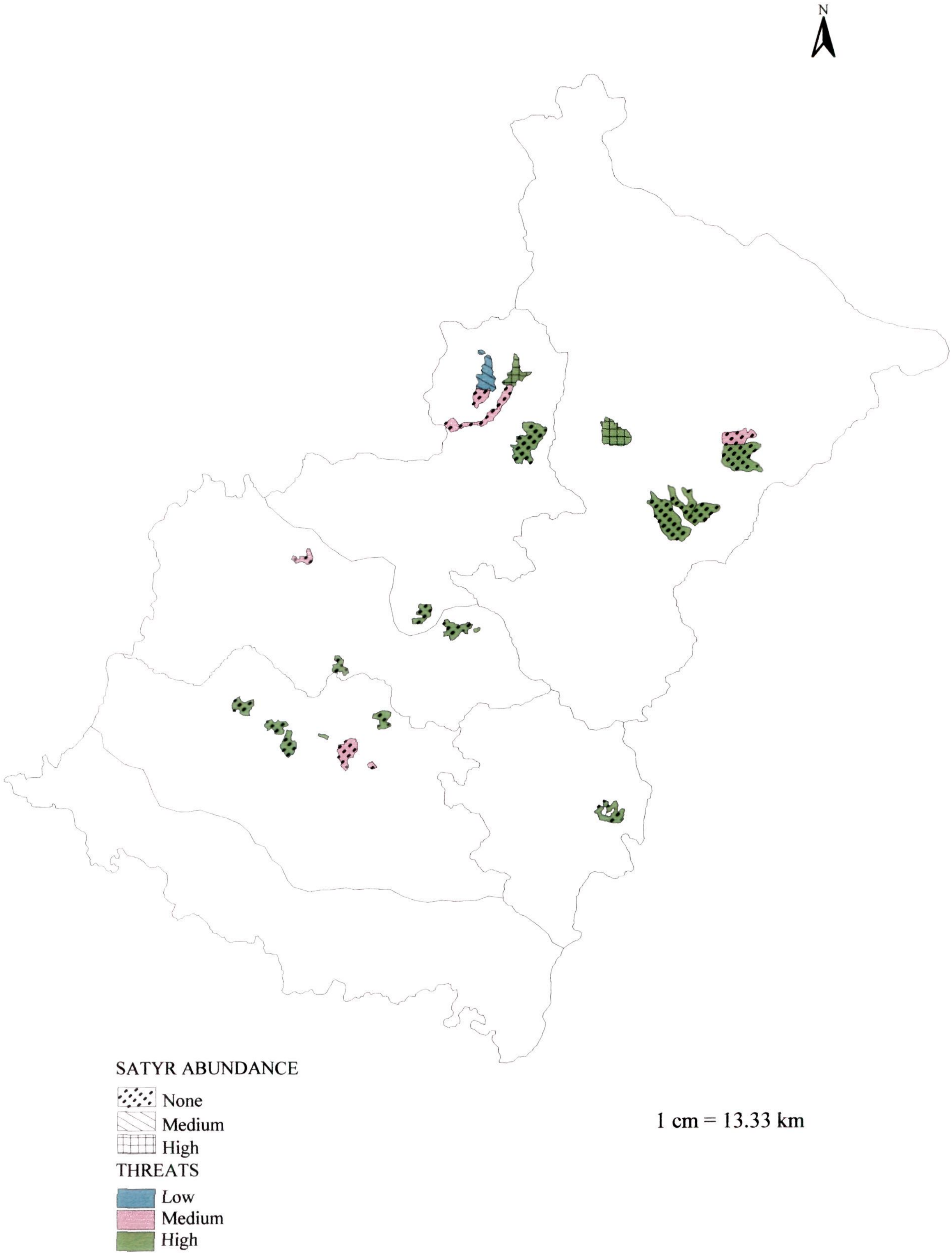


Fig. 8.14 Satyr Tragopan abundance in relation to threats in Kumaon Himalaya.

map high threat areas were having high Satyr abundance, and at low threat area in Sunderdunga the abundance was medium (Fig. 8.14).

8.4 DISCUSSION

The greatest damage to natural habitat and wildlife today is due to ever-increasing exploitation of land and natural resources. The niche of human is expanding at the expense of other species. The ever-increasing exploitation is resulting in damage, loss and fragmentation of natural areas in all continuously inhabited parts of the world; whether it be desert region, temperate region or tropical (Pyne, 1981). Himalayas too suffered with similar trend in resource use. Himalayas hold a significant unit in the Indian subcontinent and is being utilized as supplier of natural resources by human since the start of the civilization in this region. Later the origin and settlements in and around the valleys depleted the biodiversity values of the entire region. The over crowding led to resource crunch and compelled them to move and expand upto the higher elevation in the difficult and remote areas. In due course of time the newly inhabited areas experienced similar threats as the previous ones at lower elevations.

Kumaon Himalaya which hold 4.70 % of land of the Himalayas within the Indian limits, extend from lower to higher Himalayas, and it can be considered as representative unit possessing all climatic conditions experienced by entire Himalayan region. The region is densely populated by human beings and well connected with road transport throughout its range. The easy approach to most parts of the region lead to the development of the area, as is being happening in other parts of the Himalayas. Consequently, random forest clearing was observed from various disturbance activities for the purpose and most parts of the region are asserting severe threats to the survival of pheasant species. But still this region holds all the representative pheasant species since long time.

The present study was conducted for the assessment of various threats on different pheasant species of Kumaon. The scattered human settlements from foothills to sub-alpine zone supported different kind and intensity of threats, which showed the specificity and magnitude at different representative locations. I identified 23 parameters as threats to pheasant conservation. Out of 23 surveyed sites, fire was found at Daphiadhura, Jageshwer and Binsar Wildlife Sanctuary. According to the reports of the forest department the maximum wide spread fire event with an affected area of 460km² was observed during 1984 in whole of Kumaon and again after a span of 10 years i.e. 1995, the affected area under fire was 309km². The occurrence of fire at the rest of surveyed oak patches was low. Kilbery, Jilling, Mukteshwer, Gasi, Dhakuri, Wachham, Sunderdunga, Pindari, Sobala, Duku, Munsiary and Mechh did not experience fire in the recent past. But recurrent fire events have been observed from the beginning of the 20^{th} in the Naini Tal forest division (Working Plan Naini Tal Forest Division, 1988-1998). Kilbery and Mukteshwer are densely populated and regularly grazed by cattle. Kilbery forest is in continuation with Naini Tal main township and visited by thousands of tourists every year while in Mukteshwer, a branch of IVRI Bareilly office exists inside the forest patch and is inhabited by >6000 people. Yet these two sites did not experience frequent fire in the past. The reason may be the Kilbery is near to Naini Tal, which is also head quarter of the Kumaon Forest division. Regular checks and vigil by forest department must have prevented intentional fires as have been experienced by other remote areas. The same is true for Mukteshwer too where it is managed jointly by IVRI officials and the forest department. The forest department has established a special unit inside the IVRI campus and a ranger has been deputed for the conservation and management of Mukteshwer reserve forest. This could be the reason that the species like Cheer was encountered at Vinaiyak (Hussain *et al.* 1997) and Mukteshwer (Rasool, 1984). The status of Jilling was different from the rest of oak patches. It was a privately owned estate of small area of <3 km² in size. The owner of the estate did not allow any destructive activity inside this patch and maintain strict vigilance to extinguish fire if occurs at any corner. This could be the reason for Jilling though it was surrounded by many dependent villages, did not had any fire in the recent past and possessed a good population of Kalij pheasant in such a small area. However, there were reports from local people of the presence of Cheer pheasant at Jilling (Kaul, pers. comm.). Mechh was found to be highly degraded by having maximum dependent human and a sizeable livestock population. The houses were situated very close to and in the vicinity of the forest. At this patch, it was enquired from the forest guards that locals extend great help to cease forest fire that's why this site too did not experience any fire in recent years.

Gasi, Dhakuri, Wachham, Sunderdunga, Pindari, Sobala, Duku and Munsiary never had forest fire in the past. These sites are located at higher Himalayas with the altitude starting >2600m leading to sub-alpine and alpine meadows. Specific to their location, these sites were not frequently visited either by locals or by tourists throughout the year. Besides, being very close to snow clad peaks and immediate barrier of the Himalayas, these sites receive frequent showers and long duration snowfall. This makes the ground wet and humid that might be the reason to make these areas free from intentional or accidental or natural fire event. Most of the sites represented maximum pheasant species composition, but the sites in the group where no pheasant species or low representation of pheasant, might be due to sampling effort or some other reasons which could not be traced.

Pandavkholi was a sacred place and locals as well as visitors visit here. This patch had a well-established temple complex inhabited by many saints. The site was free from any kind of forest fire and if it occurred, locals were highly devoted to cease it. It supported good forest cover and understorey vegetation for the species like Kalij and Koklass respectively. Sitlakhet was in highly degraded condition. Most of the vegetation was sparse and mostly consist of pine forest, which did not support suitable pheasant habitats.

The intensity and expansion of forest fires at Daphiadhura and Jageshwer was low and in small areas (0.01% and 0.005% of their representative areas in Kumaon respectively) as compared to Binsar Wildlife Sanctuary where upto 30% of the sanctuary area was under intensive fire. The fire at these sites was classified as class 2 according to classification of Van Wagner (1983). It was observed that all the vegetation layers were found to be badly affected. Secondary layers, mostly the shrubs and tree species at the sapling stages were found dead, which must have affected the ground dwelling pheasant species at these patches. I found only Kalij and Koklass at Daphiadhura, although the habitat at fire location was found suitable for other species like Monal and Satyr Tragopan. Many workers (Heinselman, 1981; Kilgore, 1981; Christensen, 1981; Mueller-Dombois, 1981; Fox *et al.* 1985; Hulbert, 1988; Midgley & Clayton, 1990; van Hansbergen *et al.* 1992 and Bond & van Wilgen, 1996) have documented that post fire conditions have many advantages for seedlings. Fire stimulates vegetative reproduction of many woody and herbaceous species when the upper layer is reduced. Sprouting from *Quercus* sp., *Alnus*, *Rhododendron* was mostly observed in Binsar, Jageshwer and Daphiadhura. But other face of fire was equally bad for these forest patches. The fire opened the canopy and created gaps. The worst part of fire in terms of adverse affect on pheasant was that people were seen cutting the burnt trees and the affected forest patch would ultimately become a permanent gap until the regeneration reaches at the level of native forest.

There is general consensus that fires are responsible for insignificant levels of direct faunal mortality, fire size and seasonality influence animal survival (Spellberg *et al.* 1996). During the assessment of fire, no dead mammal or pheasant species were encountered. The literature on the effects of fire on fauna is not enough. Part of the reason is that it is difficult to pinpoint cause and effect relationship between the action of fire and the response of animals. This might be due to the cause that sudden and drastic modification of habitat due to fire at these sites created inhospitable habitats. The fire was assessed after one year and large scale cutting of the dead trees in these areas has created large gaps, which detracted large mammal and secretive birds, especially pheasants to utilize it as cover or for food.

Besides fire (abiotic factor), which had detrimental consequences, other factors (biotic) also imposed significant threat on pheasant species of Kumaon. The nature, kind and intensity of these threats varied from patch to patch or groups of patches experienced similar kind of threats and the prevailing threat factors someway or the other affected composition and abundance of pheasant species. Out of all the threat factors, it was observed that the human factor residents or tourists, and their relative activities regulated possession of livestock, land area holding capacity for different purposes directly or indirectly leads to habitat loss which is direct threat to the pheasant species survival (Fuller *et al.* 2000).

General increase in the livestock population was observed with the increase in human population in different localities of Kumaon. The livestock depend on the forest in two ways firstly, the forest is used for grazing round the year, and the cattle feed on young plants, and the leaves and twigs of small plants. Secondly, the leaves and twigs of oak trees are lopped and grass harvesting for cattle feed. The lopping activity creates gaps and opening inside the forest, which may not be favourable habitat for close canopy species like Kalij (Hussain *et al.* 2001) and Satyr Tragopan (Khaling, 1998).

8.4.1 Intensity of biotic pressure to pheasants at various locations of Kumaon

On the basis of generated threat index, Jilling and Sunderdunga were considered as low threatened areas. Though both the areas had fallen in the same category of threat but the characteristic of these areas were totally different from each other. Sunderdunga in spite of being a large forest patch was devoid of any human habitation. It had very low number of human presence in the form of tourist during summer and autumn seasons. High degree of medicinal plant extraction, lichen & moss collection and poaching of species like Monal pheasant and Satyr Tragopan were the major threats experienced by this patch. This area was inaccessible most of the time of the year. Moreover, most of the considered threat attributes were not found here so it was considered as a low threatened area. Jilling was a small forest patch, which has least conservation potential in terms of area and pheasant species composition. But being a privately owned estate, it enjoyed as a protected area status and here all the activities (cutting, lopping, grazing etc.) were practiced for personal use only.

15 sites were recognized similar on the basis of threat parameters evaluated at these sites. Group of sites Kilbery, Maheshkhan and Pandavkholi had good forest cover but to some extent they were facing high degree of threats in terms of lopping, cutting, grazing, grass harvesting, fuel wood and received sizeable number of tourists every year and they represented only Kalij and Koklass. The second group included Gasi, Wachham, Duku, Mechh and Mukteshwer. But except Wachham, where four pheasant species including Cheer and Monal were found, none of the other sites in this group represented Cheer or Monal.

Binsar Wildlife Sanctuary (BWS), Sitlakhet, Jageshwer, Pindari, Gandhura (Askot Wildlife Sanctuary) and Munsiary were highly threatened areas in terms of habitat loss. Pindari, Gandhura and Munsiary were very large forest patches while Binsar, Sitlakhet and Jageshwer were relatively smaller. But the intensity of threat was very high at all these patches. In spite of being a protected area BWS faced many threats. The number of dependent villages (32) and human & livestock population was very large so lopping, cutting, grazing, grass harvesting and fuel wood collection were at large scale (Fig. 8.15). A metalled road passes through the sanctuary and goes upto the highest point of this sanctuary, which allowed heavy transport of tourists and vehicles. There were four privately owned estates situated in the core zone area and they occupied dense oak-forest Fig. 8.16). The owners of these estates had cleared the surrounding forests for orchards, agricultural practices and construction work. Collectively all these activities speeded up

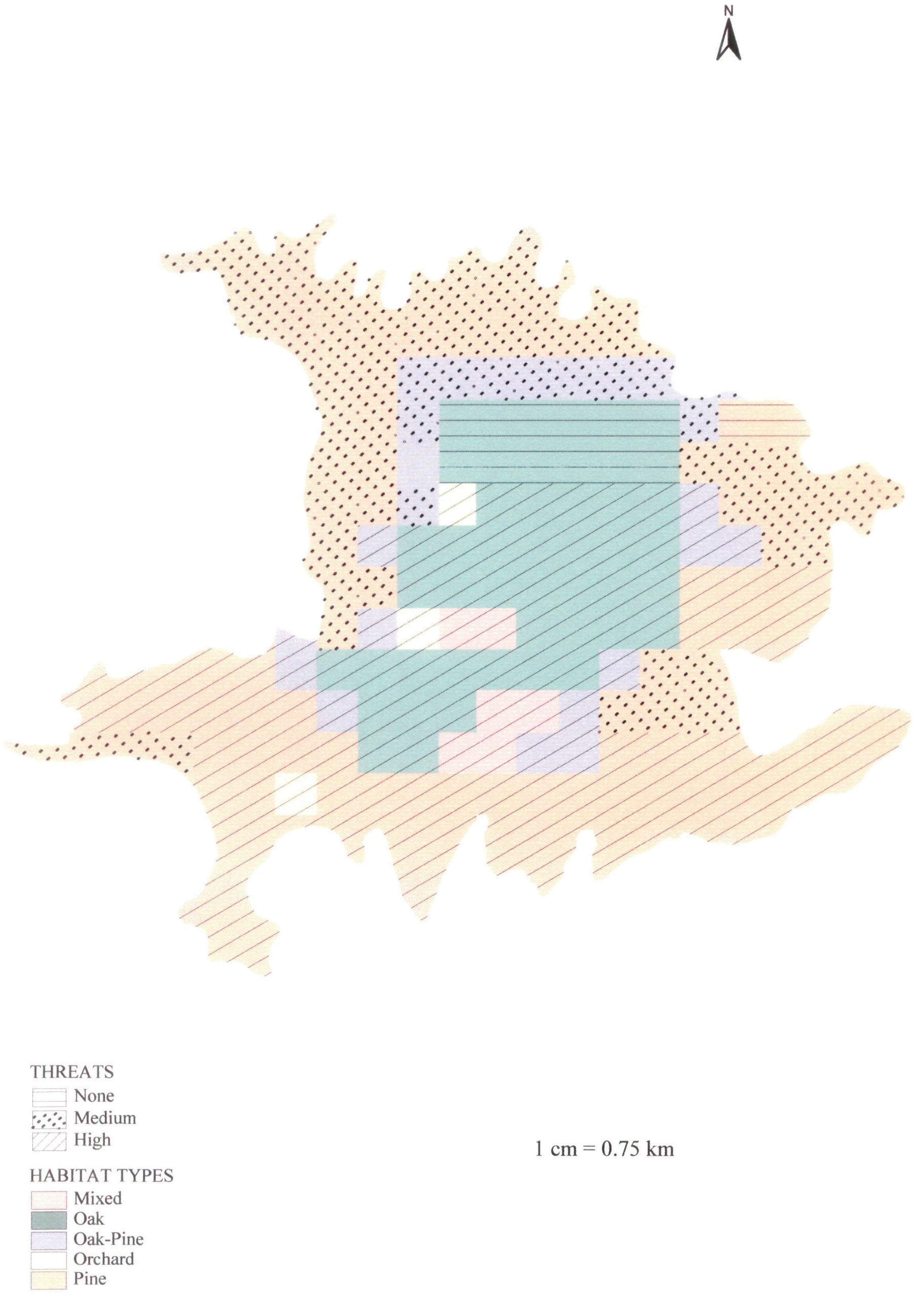


Fig. 8.15 Intensity of threats in different habitat types in Binsar Wildlife Sanctuary.

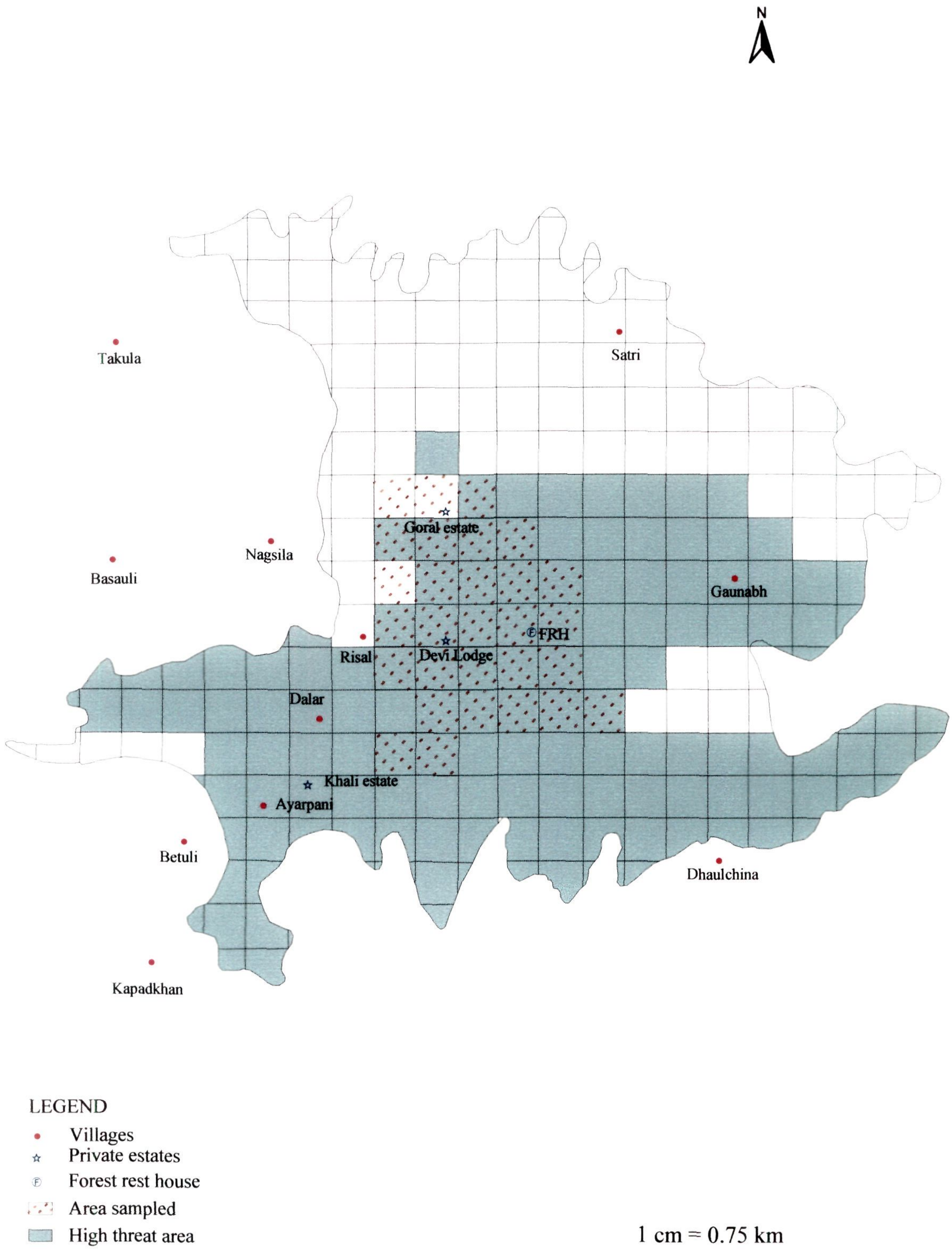


Fig. 8.16 Assessment of biodiversity values at the areas experiencing maximum threats in Binsar Wildlife Sanctuary.

thinning and degradation of habitat at faster pace. Consequently, the species like Cheer, which used to be present in the area, have been locally extinct from the sanctuary. During my two years of stay I have neither heard nor sighted or found any indirect evidence of Cheer though I have conducted one year of my intensive study in this particular area. Recently, during the study period, it was observed that renovation work of one of the abandoned estates had been started inside the sanctuary which supported good forest cover around it and the species like Koklass and Kalij had been sighted frequently around the vicinity of this long abandoned building but its functioning in due course of time will certainly affect the presence of these species. Moreover, heavy toll on trees for the purpose will further degrade the forest area surrounding the resort in due course of time. It may also alter habitat, which may activate in the disappearance of some more species of pheasants from the area in near future as Cheer has disappeared.

The situation in Sitlakhet is worse than BWS though both have been grouped in a single cluster. Most of the area in Sitlakhet was in highly degraded state and surrounded by pine forest. Being close to Almora city, it was densely populated with human and livestock population and was well connected with road network all around. It was devoid of dense oak forest so people mostly depend on the degraded oak forest to meet their needs of fuel wood and fodder. Most of the broad leaf tree species were found lopped, and the cutting together with lopping was so intense that only stunted trees without branches were found at this patch. There was no direct or indirect sighting of any pheasant species. Evidences of occasional sightings in the past by locals of Whitecrested Kalij was recorded from this site, which indicated past habitat condition to be good in terms of habitat health for pheasant therein.

Pindari formed separate group in terms of existing threats therein. But the area was unique in keeping all the representative pheasant species of Kumaon as compared to other surveyed location of Kumaon. Maximum numbers of pheasant species have been encountered in this area. Being representative of maximum pheasant species, it also represented vulnerable Cheer pheasant. Poaching and egg collection of pheasant species was for meat only.

The alpine and sub-alpine zones of Pindari were rich in medicinal plant species, which were extracted for local use as well as for commercial purposes. These medicinal plants formed major composition of vegetation at the herb layer. The extraction of medicinal plant takes place during the flowering season of these species. These medicinal plants along with other associated herb species are food-base for species like Himalayan Monal. I personally observed Monal feeding on the roots and tubers of plant species like *Orchis latfolia, Acotinum heterophyllum* and *Dactylorhiza hatazirea.* While at shrub layer *Arundenella nepalensis* was heavily extracted for its products for local use as well as for commercial purposes which may affect Satyr Tragopan population in near future and the species may become locally extinct from the area.

Sheep and goat grazing was found very high. Regular pastoralists having >10,000 sheep and goats were found roaming throughout the area during different months of the year at different places in the entire Pindari region. Owing to heavy sheep & goats grazing, the ground cover of the area was found to be heavily grazed and consequently low abundance of seedlings of plants was observed. Pindari region is known for three world famous glaciers namely Pindari, Kafni and Sunderdunga, and these places attract thousands of tourists during summer and winter every year. The trekking routes to these glaciers pass through prime habitats suitable for pheasant species. Along the way to these glaciers facilities for the tourist stay were available at some places. For providing basic facilities and needs, these places have been developed into a small gathering of locals and their number is increasing every year to get local employment, as a tourist guide. All the basic requirements whether it be fuel wood, timber and sometimes meat of pheasant species for the tourist are extracted from the surrounding forest. Day by day clearing of forest was taking place to meet the need of the tourist. Locals had expanded there infra structure facilities like opening of more small restaurants and they were also constructing small cottages specifically built for the tourist stay. All these activities adversely affected pheasant habitats. Besides, tourist inflow in large number creates disturbance to the normal activities of the almost all the pheasant and mostly during summer, which is the breeding season of all the Himalayan pheasant (Ali & Ripley, 1987, Johnsgard, 1986 and Grimmett *et al.* 1998).

The last point of Pindari glacier trekking route leads to the base of the Nanda Devi peak which falls in the vicinity of Nanda Devi Biosphere Reserve and which has been declared as World Heritage Site by UNESCO's Man and Biosphere (MAB) program in 1992. This is the home of so many endangered mammal species like Musk deer, Snow leopard, Himalayan Tahr and Blue sheep and pheasants such as Himalayan Monal and Satyr. Here exist a small temple where tourist enjoy the close view of the glacier and spend few hours and go back to the last stay point at Phurkia. Now a days, this temple is expanding at large scale in its area and structure, which may attract large number of pilgrims and tourists in future and may become a serious factor for the habitat loss of the area in general and major threat to the pheasants of the area in particular.

8.4.2 Conservation assessment of pheasant species as well as localities

A general conservation assessment index generated by including habitat as well as anthropogenic factors into analysis revealed significant association between threat factors and habitat condition. The habitat factor altitude played significant role in controlling magnitude of disturbance factors at various altitude ranges. The significant negative correlation of altitude with disturbance factors was observed in overall Kumaon and species like Monal and Satyr, which are supposed to be the primary forest and less disturbed habitat occupying species were present in those areas as compared to Kalij or Koklass which can tolerate some level of disturbance within the habitat they occupied in Kumaon. The species such as Himalayan Monal, Satyr and Cheer pheasant achieved higher conservation status in Kumaon as compared to Kalij and Koklass.

Himalayan Monal and Satyr Tragopan occupied narrow distribution range while Cheer has been declared as vulnerable by IUCN (Fuller *et al.* 2000) hence these species need more attention in conservation efforts for its survival in the region as well as in maintaining larger distribution range. Moreover, areas represented by these species in Kumaon are also not accorded with the status of Sanctuary or National Park so that better legal protection could be provided to these species.

Though the species such as Himalayan Monal and Satyr Tragopan are endemic to Himalayas but they occurred on the fringes in Kumaon, were given more emphasis while analyzing data to conserve these species on priority basis. Satyr Tragopan has its western limit in Garhwal Himalaya but it is hard to confirm the presence of the species there. But recent surveys in Kumaon have confirmed the presence of species (Hussain *et al.* 1997) in narrow range. Cheer which is vulnerable species (IUCN, 2000) and the patchy nature of its specialized habitat may render the smallest, isolated population vulnerable to extinction, and higher levels of disturbance (e.g. grazing and felling of wooded ravines) posed substantial threats to the species (Kalsi, 1998). The unique habitat requirement of Cheer, which does not fall in any of the 11, described vegetation types of the Himalayas documented by workers (Champion & Seth, 1968; Puri *et al.* 1983 and Gadgil & Meher-Homji, 1986a & b) are not represented in significant unit in their distribution range also made the species to be given a priority for its conservation.

Any animal species is better conserved if their habitats are equally conserved (Rands, 1989). Keeping this in view, conservation assessment of various locations of Kumaon on the basis of pheasant species composition and their abundance was obtained. Pheasants being indicator of habitat and their status in any natural habitat can be considered an index of the quality of the well being of that ecosystem (Jayal, 1982). So, various surveyed forest patches of Kumaon Himalaya obtained varying degree of conservation status and they have shown quality of habitat they maintained on this basis. Pindari and Wachham gained higher conservation status in terms of pheasant species composition than the other sites. Though both the sites were ranked in the higher threat index category than the Sunderdunga and Vinaiyak (Table 8.20) yet emphasis for better conservation is needed for the sites Pindari and Wachham because these sites inhabited the vulnerable species like Cheer and other species such as Satyr Tragopan and Himalayan Monal, which obtained higher conservation status in the Kumaon. Vinaiyak retained higher conservation due to presence of Cheer while the sites Sunderdunga and Munsiary were also equally important in terms of pheasant conservation. Both sites retained equal conservation status by having Satyr Tragopan and Himalayan Monal. Both areas have shown dissimilarity in threat intensity upon pheasant species. Sunderdunga seemed to be the least disturbed area among other sites while Munsiary had fallen in high threat category but some of the areas of Munsiary still retain suitable habitat for species like Himalayan Monal and Satyr Tragopan and hence given equal emphasis to conserve these species. The rest of the sites retained lower conservation status by having Kalij and Koklass in the larger range in Kumaon.

8.4.3 Conservation strategies and recommendations for pheasant species conservation.

The present study was aimed to study the threats on pheasants of Kumaon Himalaya and to prepare conservation strategies for them. The main three queries of conservation i.e. what to conserve? Where to conserve? and How to conserve or Recommendations; will be discussed in the light of the outcome of intensive study on pheasants and threats.

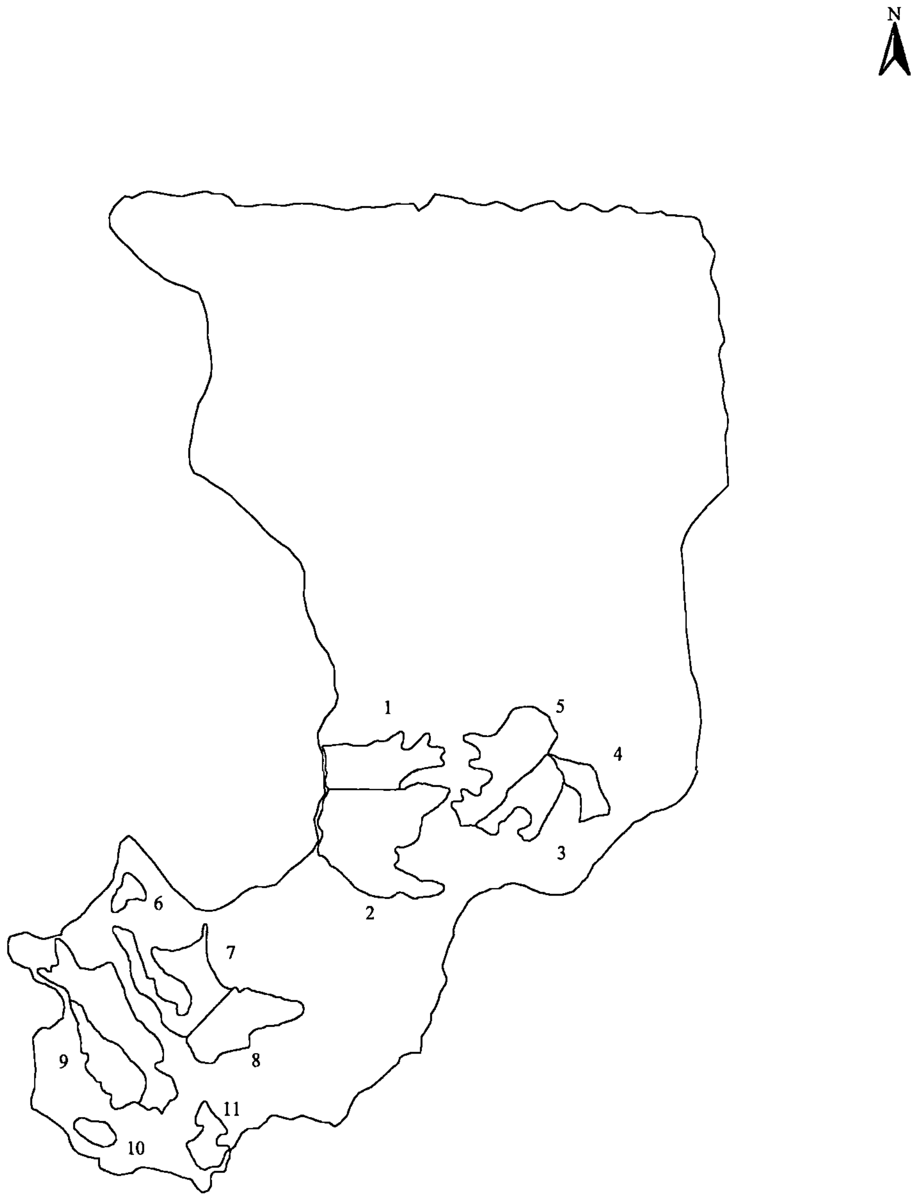
8.4.3.1 *Where to conserve?*

In the Kumaon Himalaya, temperate forests include habitats of mixed broad leaves, moist oak and rhododendron and dry coniferous of pines and firs; higher up, sub-alpine forest of birch, rhododendron and juniper occurs. The forest areas of this region are particularly important for many pheasant species. This unit of Western Himalaya includes the probably extinct Himalayan Quail, which was once distributed in Naini Tal region, and other the Cheer pheasant (*Catreus wallichii*) is thought to be at risk of extinction, sighted in Pindari and Vinaiyak areas only. Another pheasant, Satyr Tragopan

(*Tragopan satyra*) is also restricted to the Kumaon Himalaya towards its western limit. Its occurrence in Garhwal Himalaya is in question (Gaston, 1982). Both the species are threatened by habitat loss and degradation and hunting. In whole bird community, pheasanidae suffer a lot by human beings.

The first stage of most conservation planning is to identify areas that need protection. The main criteria used to identify such areas are biodiversity, rarity, population abundance, environmental representativeness, and site area. Where distribution data are both comprehensive and accurate, it is possible to identify areas of high species richness for certain taxa, focusing on threat level (e.g. endangered species) or biogeographical status (e.g. endemic species) (Diamond, 1986; Myers, 1990; International Council for Bird Preservation, 1992; Prendergast *et al.* 1993 and Dobson *et al.* 1997). In past, the protection of individual, usually rare species was used to select the site for protection but this approach to reserve selection has its strength and weakness (Prendergast *et al.* 1999). Pheasant species are part of overall biodiversity so as to make the former more holistic, it must therefore encompass the whole range of plants, animals and microorganisms.

There are only two sanctuaries existing in Kumaon i.e. Askot Wildlife Sanctuary (Pithoragarh district, area = 600 km^2) (Fig. 8.17) and Binsar Wildlife Sanctuary (Bageshwer district, area = 45.59 km^2) (Fig. 8.18). The percent (3.1%) protected area is too small as compared to whole geographical area of Kumaon (2,1032 km^2). Both the sanctuaries were facing severe threats. Binsar sanctuary has limited conservation potential having only approximately 4 km^2 of oak patch (Fig. 8.19). This patch is just like an island without any connection with another oak patch. None of the areas are



LEGEND

1	Sobala	(Surveyed)
2	Duk	(Surveyed)
3	Jiunfigard	
4	Rungling	
5	Ahirigomri	
6	Thakla	
7	Dhaphiadhura	(Surveyed)
8	Majtham	(Surveyed)
9	Gandhura	(Surveyed)
10	Sirtham	
11	Payan	

1 cm = 6 km

Fig. 8.17 Map showing forest patches of Askot Wildlife Sanctuary in Pithoragarh district.

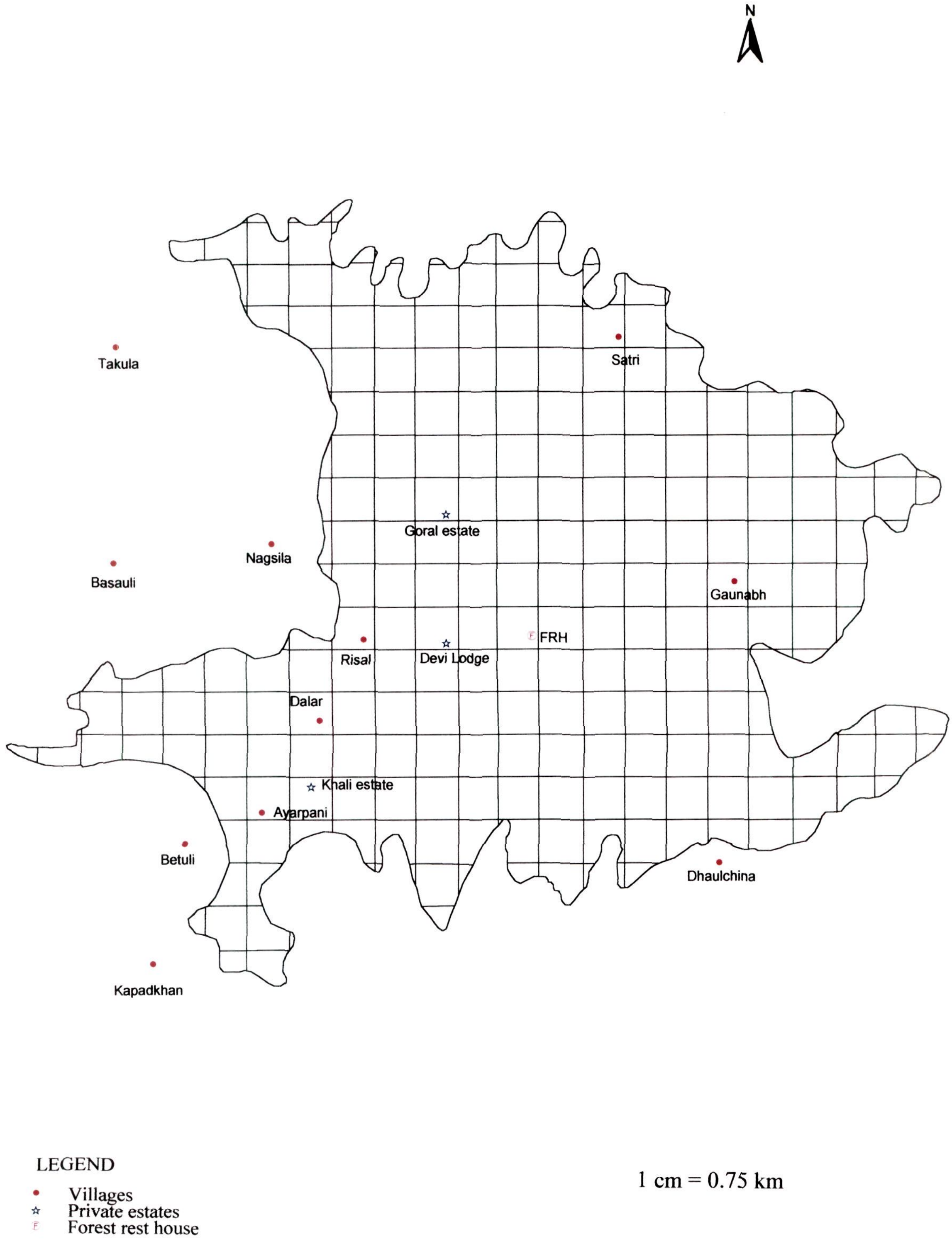


Fig. 8.18 Location of villages in and around Binsar Wildlife Sanctuary.

conserving the threatened species like Cheer and narrowly distributed Satyr in Kumaon. Therefore, in order to conserve pheasant species of this part of Western Himalaya, and as well as plant species, more areas have to be brought under the network of protected areas.

I recommend creation of two more sanctuaries in the Kumaon Himalaya in Bageshwer district (Pindari area) (Fig. 8.20) and Naini Tal district (Kilbery-Vinaiyak-Kunjakharak area) (Fig. 8.21). Blue prints of these sanctuaries were prepared from the toposheets of Survey of India. These areas hold maximum pheasant diversity and are relatively less disturbed.

The boundaries of both the proposed sanctuaries were carved out in such a manner that maximum villages were excluded. The main reason for this was to avoid conflict between villagers and Govt. officials as well as between livestock and wild animals. The Kilbery, Vinaiyak and Kunjakharak (here after Naina Sanctuary) forest patches are in continuation and also forest patches of Dhakuri, Khati, Pindari and Sunderdunga (hereafter Pindari Sanctuary) are in continuation and thus have more conservation value rather than protecting isolated individual patches such as Maheshkhan, Mukteshwer and Jageshwer.

The carved maps of proposed sanctuaries were divided into grids of 1x 1 km. Different themes (map layers) of spatial data were collected. The themes were habitat types, cutting, lopping, grazing, grass harvesting, human & livestock population, lichen & moss collection and *Arundenella nepalensis* collection. Data on all these themes were collected for each grid by visiting field and for inaccessible grid areas, data were collected with the help of binoculers and also gathered information from locals. The combination of two polygonal data themes was combined into a single digital map. The

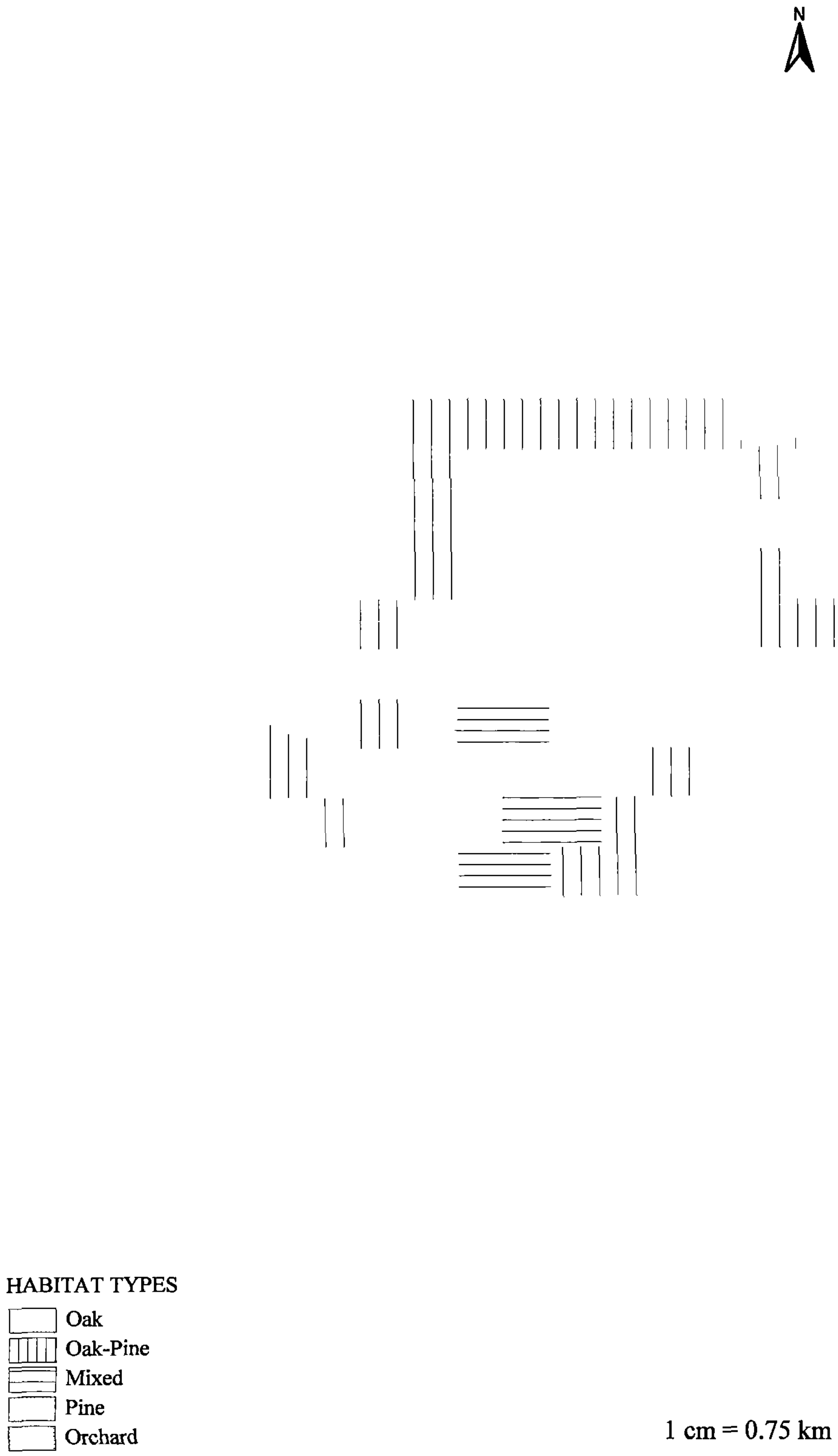
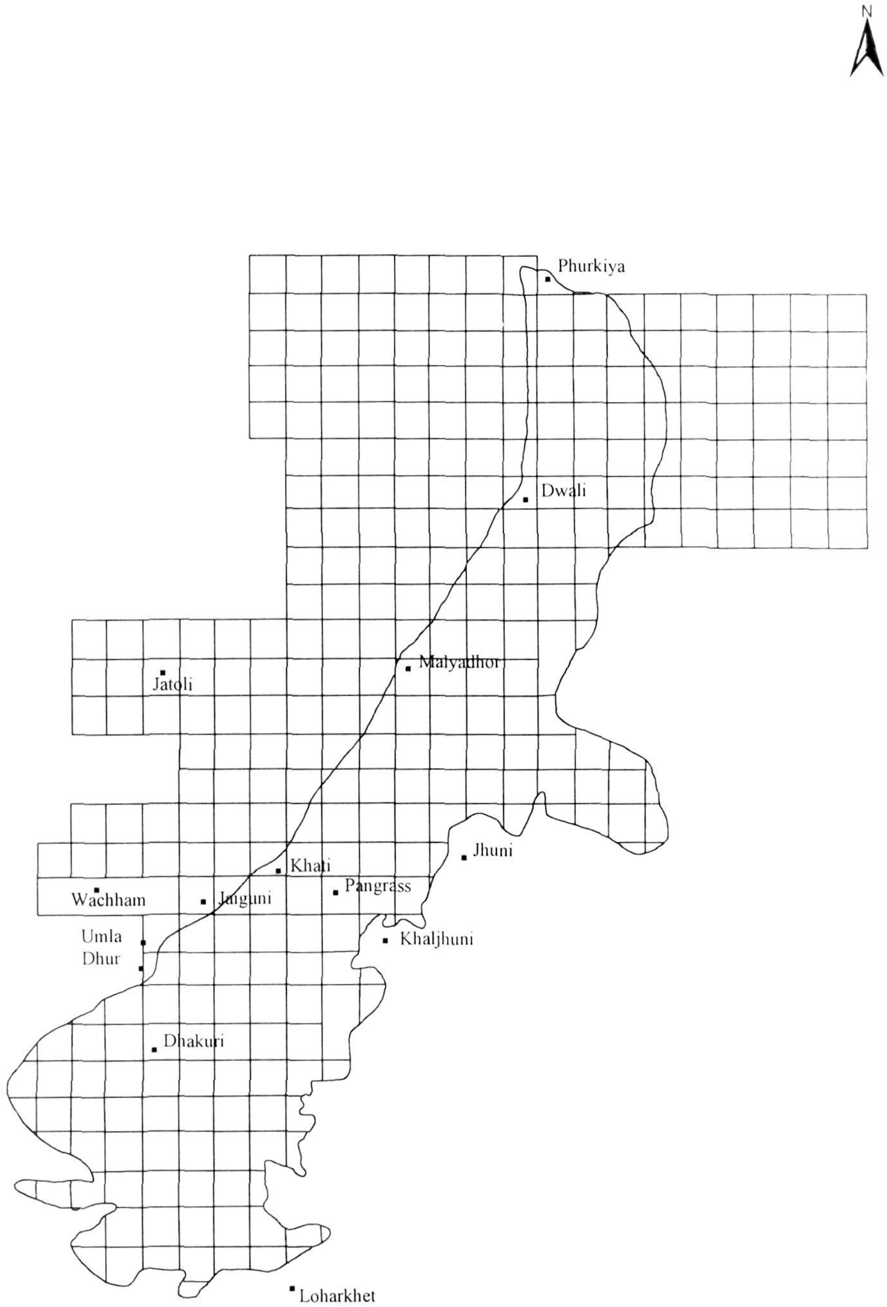
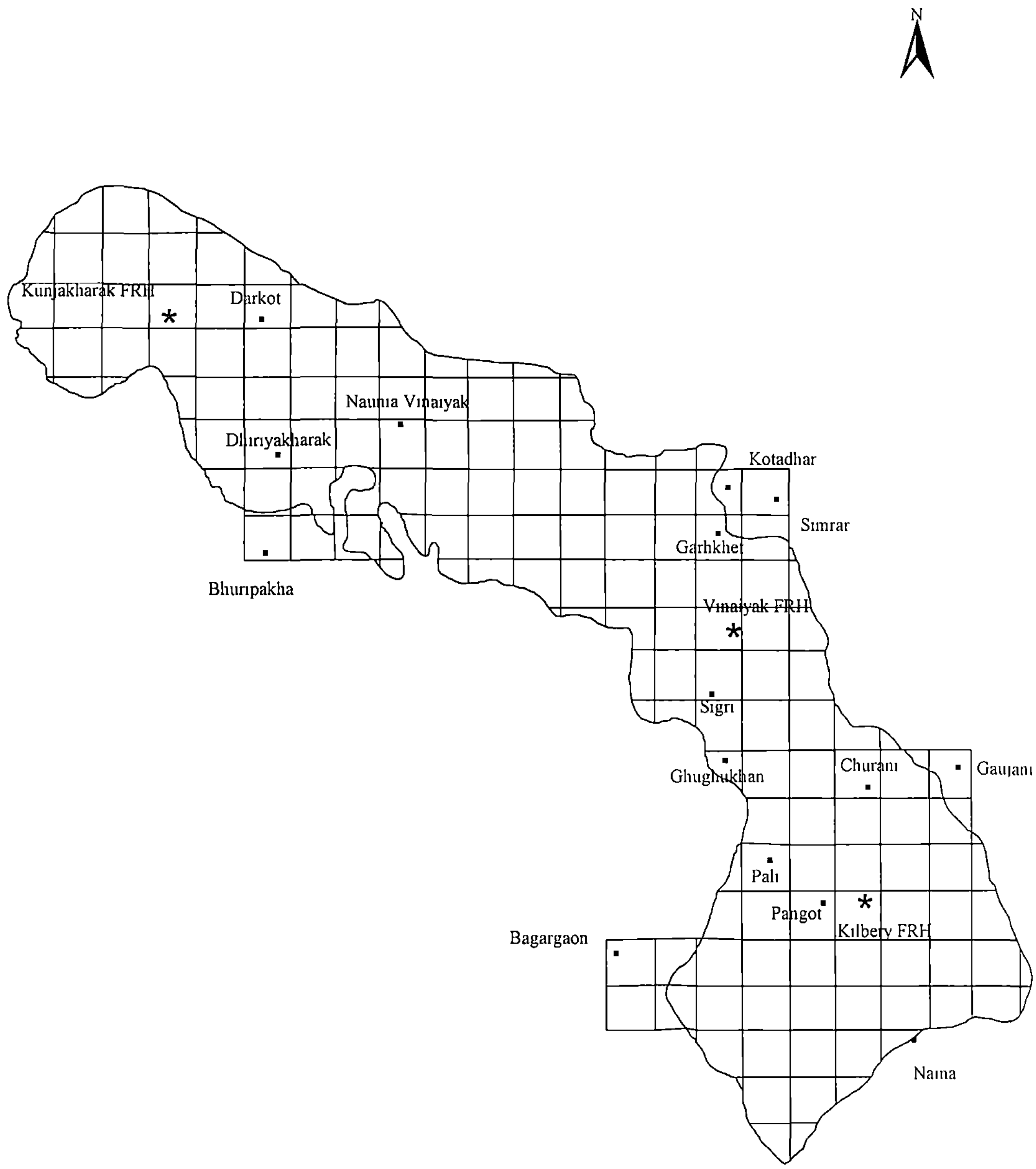


Fig. 8.19 Forest cover of Binsar Wildlife Sanctuary in Almora district.



1 cm = 1.56 km

Fig. 8.20 Location of villages in and around proposed Pindari Wildlife Sanctuary in Bageshwer district.



LEGEND

■ Villages

* Forest rest house

1 cm = 1.12 km

Fig. 8.21 Location of villages in and around proposed Naina Wildlife Sanctuary in Naini Tal district.

area of Pindari Sanctuary was figured out around 144.7 km^2 while for Naina Sanctuary approximately 87.23 km^2.

An early debate within conservation biology occurred over whether species richness is maximized in one large nature reserve or several smaller ones 'SLOSS' (Single large or several small) of an equal total area (Diamond, 1975; Simberloff & Abele, 1976; 1982; Terborgh, 1976 and Terborgh & Winter, 1980). The supporters of large reserves argue that only large reserves have sufficient populations of big, wide-ranging species and low-density species to maintain long term populations. Also, a large reserve minimizes edge effects, encompasses more species and has greater habitat diversity than a small reserve. These advantages of large reserves follow from island biogeography theory. Opposing this viewpoint, other conservation biologists argue that well placed small reserves are able to include a greater variety of habitat types and more populations of rare species than one large block of the same area (Jarvinen, 1979 and Simberloff & Gotelli, 1984). Often there is no choice other than to accept the challenge of managing species in small reserves when land around the small reserve is unavailable for conservation purposes. The land around the proposed Naina Wildlife Sanctuary (Fig. 8.22) and Pindari Wildlife Sanctuary (Fig. 8.23) is highly degraded habitat and would create problems to Government officials for its management, if it is protected. It is clear from maps that area near the villages is degraded and there is much pressure on oak patches as compared to pine forest and mixed forest in Naina Wildlife Sanctuary (Fig. 8.24) while in alpine or sub alpine forest in case of Pindari Wildlife Sanctuary (Fig. 8.25 & 8.26). As suggested by Game & Peterkin (1984) and Soule & Simberloff (1986) that strategy on reserve size depend on the group of species under consideration as well as the scientific circumstances. A conservation area should be rounded in shape i.e. low edge to area ratio. But land acquisition is typically a matter of opportunity rather than a matter of completing a geometric pattern. Shape is not an important determinant of species richness and decisions should be made on other practical grounds (Burgman *et al.* 1988).

The boundary of Nanda Devi Biosphere Reserve (NDBR) touches the boundary of Pindari Wildlife Sanctuary and by declaring it as a protected area, the buffer zone of NDBR will act as a corridor between them or this sanctuary will be an extension of NDBR and will serve as a buffer zone or transitional zone of Biosphere reserve. Naina Wildlife Sanctuary and the buffer zone of Corbett Tiger Reserve & National Park will act as a corridor between them. These corridors would allow plants and animals to disperse from one reserve to another, facilitating gene flow and colonization of suitable sites. They would also help to preserve animals that must migrate seasonally among a series of different habitats to obtain food (Primack, 1993). Samant *et al.* (1993) also suggested some river catchment areas as botanical hotspots for conservation and Pindari catchment is one of them. Johnsingh & Rawat (1994) suggested the creation of Sharda Biosphere Reserve covering an area of 2000 km^2 in Naini Tal and Pithoragarh districts. In my opinion the proposed Sharda Biosphere Reserve has little viability considering large human and cattle populations already existing in these areas. Being adjacent to Nepal, enforcement of anti poaching laws would be very difficult in such a location. On the other hand, proposed Naina Wildlife Sanctuary has permanent forest staff for vigilance at Vinaiyak reserve forest. Moreover, the area proposed for sanctuary by Johnsingh & Rawat (1994) in Kumaon may be important for some other biodiversity values but it did

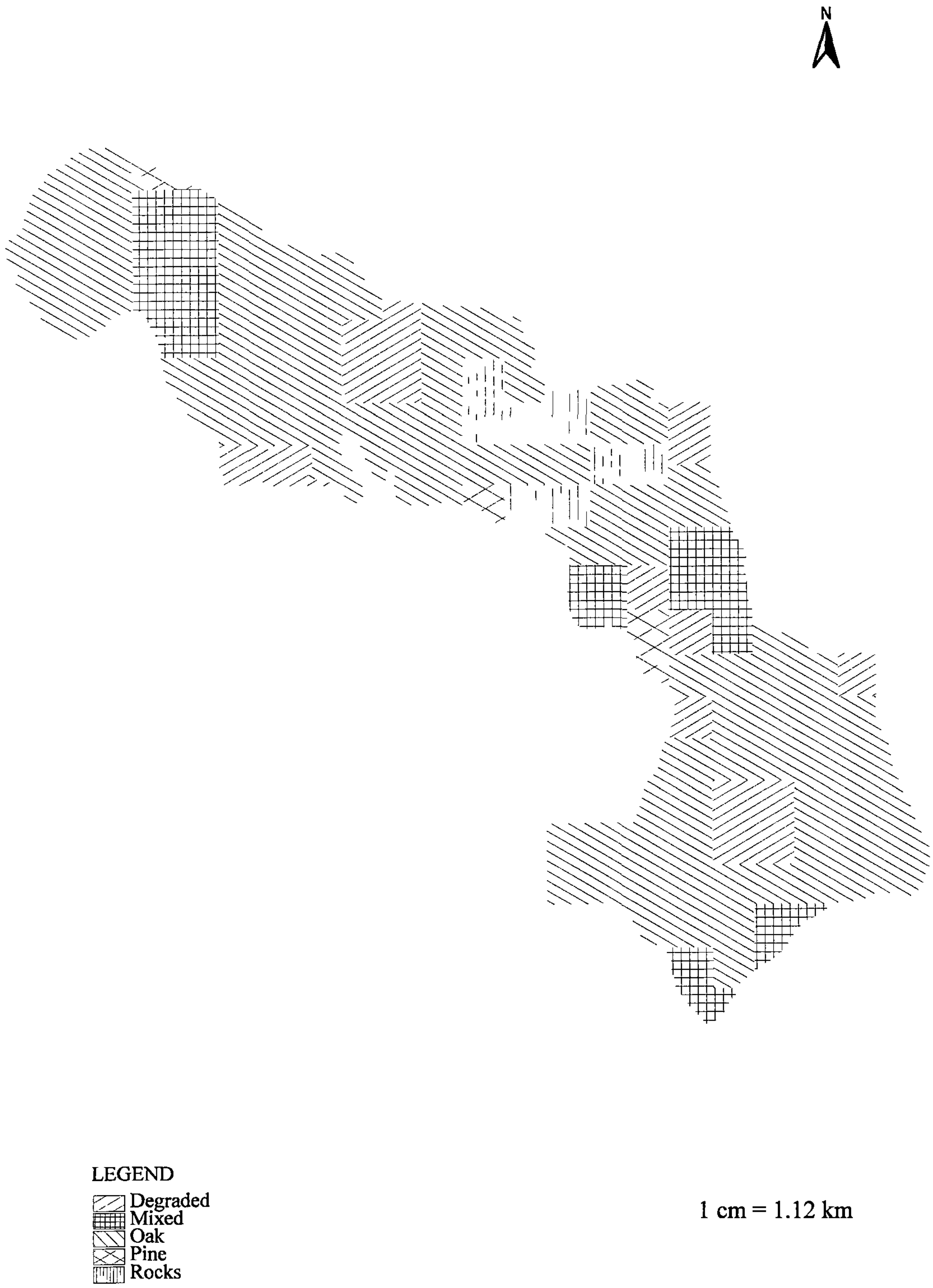
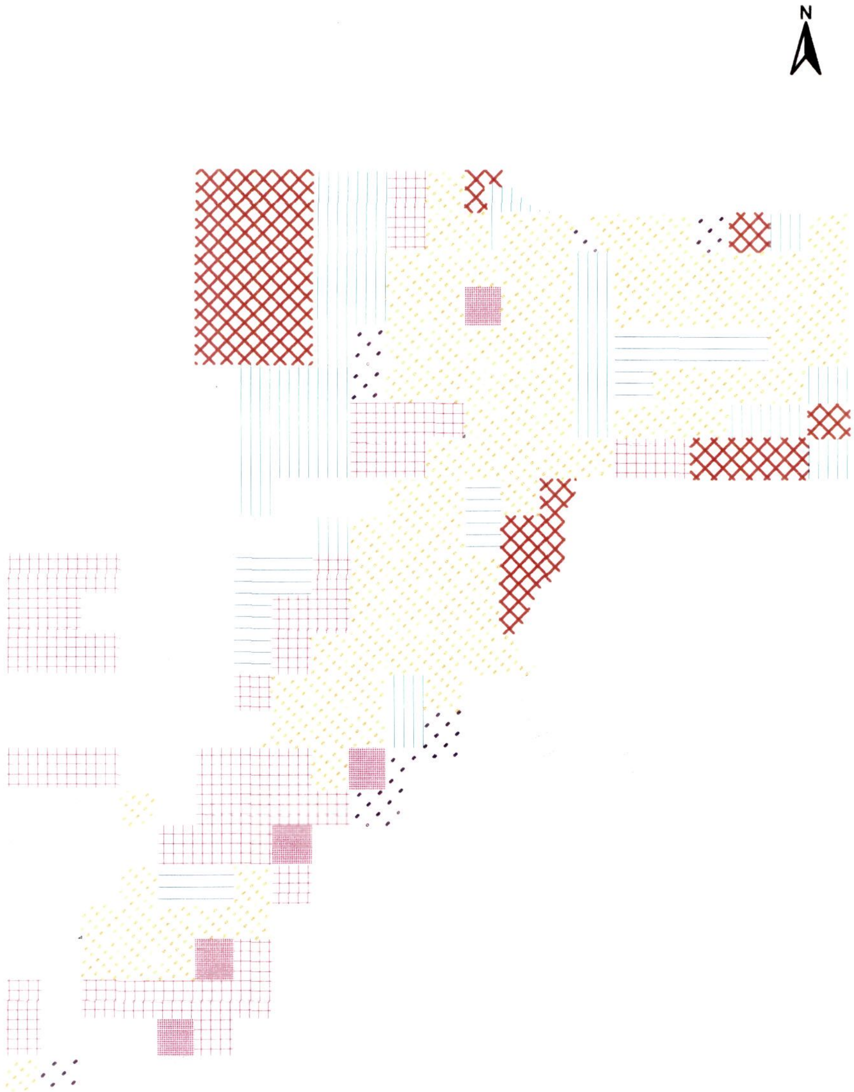


Fig. 8.22 Forest cover of proposed Naina Wildlife Sanctuary in Naini Tal district.



HABITAT TYPES

- Alpine
- Coniferous
- *Grassland*
- Grass slope
- Mixed
- Oak-degraded
- Oak-*mixed*
- Subalpine coniferous

1 cm = 1.59 km

Fig. 8.23 Forest cover in and around proposed Pindari Wildlife Sanctuary in Bageshwer district.

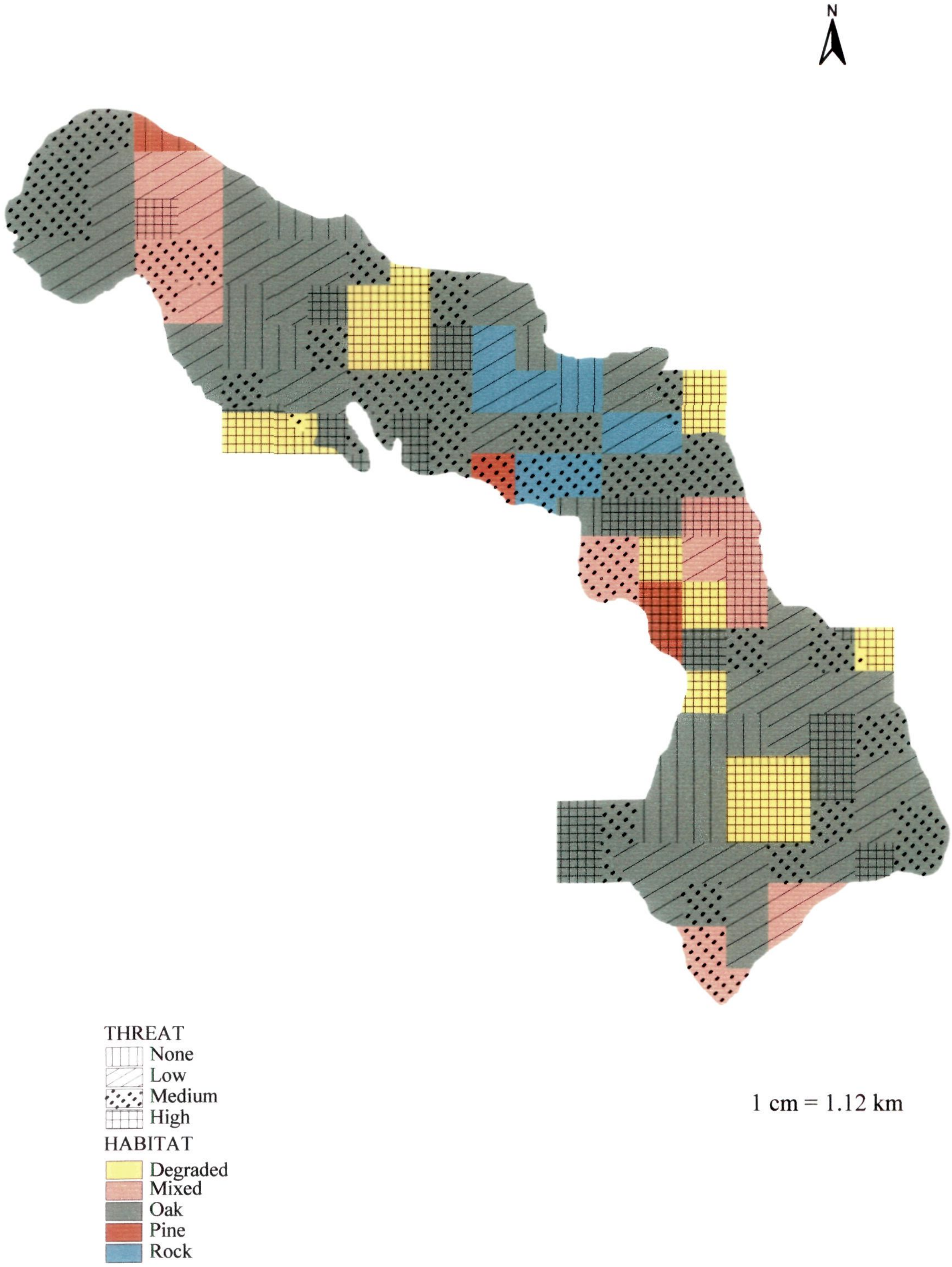


Fig. 8.24 Intensity of threats in different habitat types of proposed Naina Wildlife Sanctuary in Naini Tal district.

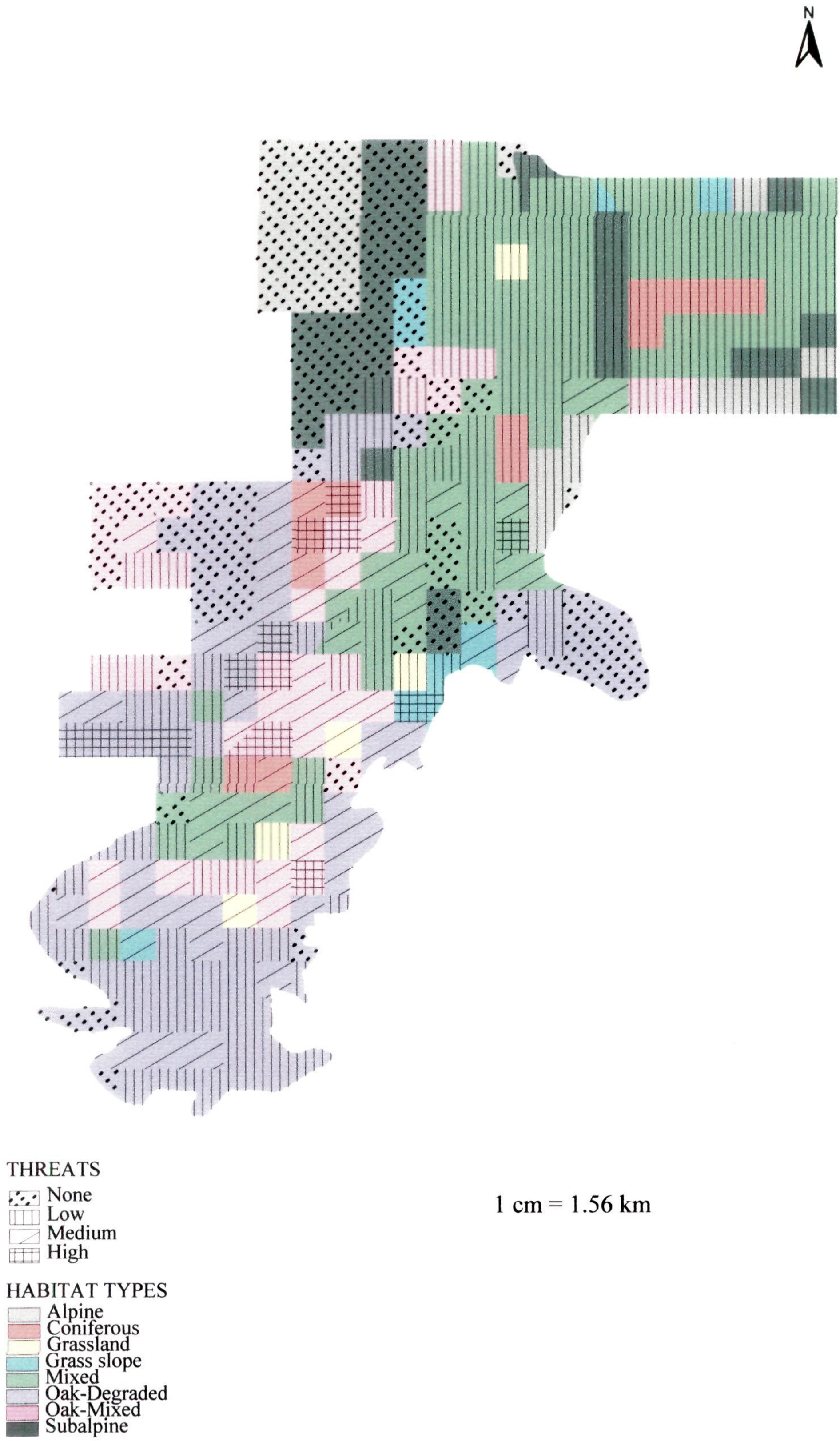


Fig. 8.25 Intensity of threats in different habitat types in and around proposed Pindari Wildlife Sanctuary.

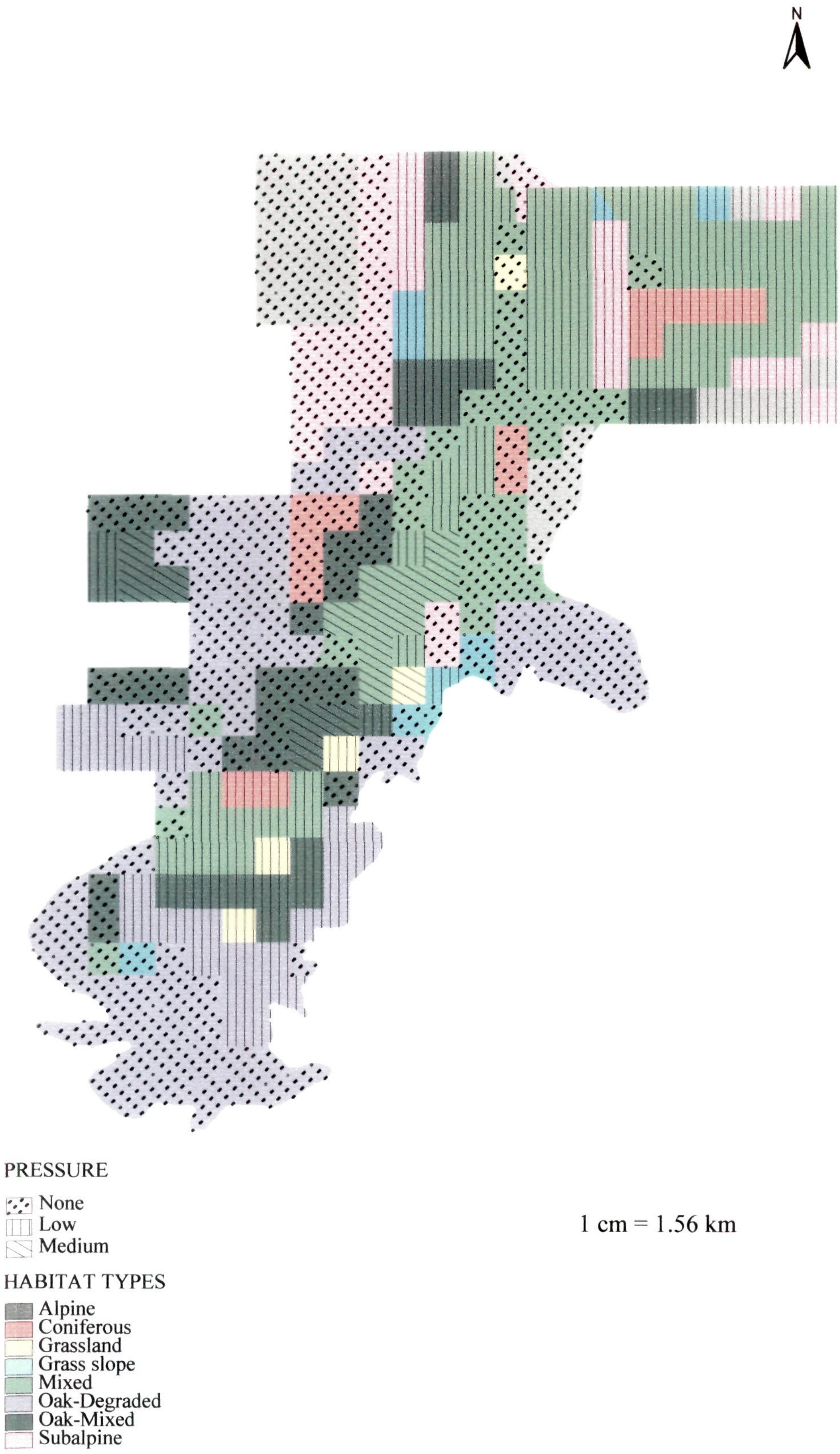


Fig. 8.26 Intensity of Arundinaria & Lichen - Moss collection and medicinal plants extraction in and around proposed Pindari Wildlife Sancturary.

not support as many pheasant species as proposed Pindari and Naina Wildlife Sanctuaries.

8.4.3.2 *Recommendations*

The exiting protected areas of Kumaon in some way or the other conserving only Kalij and Koklass. To conserve entire range of pheasants found in Kumaon, following are some of the conservation and management recommendations. It is hoped that by conserving pheasant habitat of Kumaon the biological diversity would also be conserved.

1. Areas recommended for creation of sanctuaries should be brought under protected area system soon.
2. Regular monitoring of the areas holding threatened species such as Cheer should be assessed and the possible cause of decrease if it happens should be removed.
3. No solution to hill problem is possible until and unless the number of grazing cattle is reduced. Much can be done to encourage stall-feeding and so to reduce pressure on pastures, if possible, cheap fodder can be supplied. Such fodder should be treated and made palatable. Pastures should also properly be maintained for the better feeding of the domestic animal. Rotational method of grazing should also be applied.
4. Awareness among local people about importance of animal habitat relationship is a must but it should not be assumed that they require education about tree planting and forest. Need is to supply seedlings and saplings to them and to educate them the proper method of lopping and cutting trees. However, a strong effort should be made to educate biodiversity issues to local communities.

5. Excess of tourism should be checked. As the Himalayas are rewarded with pristine natural beauty so the tourist inflow is very high here. Eco-tourism should be promoted in the existing and proposed sanctuaries. The Pindari Wildlife Sanctuary holds many fascinating mammal and bird species including all the representative species of pheasants of Kumaon.
6. There is an urgent need to examine conservation status of all types of vegetation, communities and habitats, important and selected plant and animal taxa by using remote sensing imagery, geographical information system and gap analysis. GIS analyses would make it possible to high light critical areas that should be avoided by development projects. This approach will high light correlation among abiotic and biotic elements of the landscape, help to plan protected areas that include ecosystem diversity and even suggest potential sites to search for rare species. The approach of GIS in this study was only a mere starting, a lot of work would be done in future on landscape ecology of Kumaon for the conservation of pheasants.

For the preservation of the Himalayas, for their own sake, as a system of support for the varied forms of life including pheasants, must involve equal participation of the local people of the area and national and state government. It can be achieved only by willing involvement of local people but it is for the government to take the initiative. However, it requires a positive, constructive and sustained policy for the development of natural resources.

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Appendix- List of plants sampled during the surveys of Kumaon in 1996-98.

Trees

1. *Abies pindrow*
2. *Acer cappadocicum*
3. *Aesculus indica*
4. *Alnus nepalensis*
5. *Betula alnoides*
6. *Betula utilis*
7. *Boehmeria sp.*
8. *Cedrus deodara*
9. *Castanopsis tribuloides*
10. *Coriaria nepalensis*
11. *Cupressus torulosa*
12. *Daphnephyllum himalense*
13. *Debregeasia hypoleuca*
14. *Dendroephthoe falcata*
15. *Disporum cantoniense*
16. *Dodecadenia grandiflora*
17. *Elaeagnus umbellata*
18. *Engelhardia spicata*
19. *Euonymus pendulus*
20. *Euonymus tingens*
21. *Eurya acuminata*
22. *Ficus palmata*
23. *Fraxinus sp*
24. *Ilex dipyrena*
25. *Litsea umbrosa*
26. *Lindera pulcherrima*
27. *Lyonia ovalifolia*
28. *Macranga pustulata*
29. *Maytenus rufa*
30. *Meliosma dillenaeafolia*
31. *Myrica esculenta*
32. *Panassia nubicola*
33. *Persea duthiei*
34. *Phoenix humillis*
35. *Picea smithiana*
36. *Pinus roxburghii*
37. *Pinus wallichiana*
38. *Prunus cornuta*
39. *Prunus sp*
40. *Pyrus pashia*
41. *Pyrus vestita*

42. *Quercus floribunda*
43. *Quercus glauca*
44. *Quercus lanuginosa*
45. *Quercus leucotricophora*
46. *Quercus semecarpifolia*
47. *Rhamnus triqueter*
48. *Rhododendron arboreum*
49. *Rhus spp.*
50. *Stranvissia naussea*
51. *Swida oblonga*
52. *Swida spp.*
53. *Symplocos chinensis*
54. *Symplocos theifolia*
55. *Taxus baccata wallichiana*
56. *Toona serrata*
57. *Tsuga demosa*
58. *Ulmus wallichiana*
59. *Viburnum coriacieum*
60. *Viburnum erubescens*
61. *Viburnum mullaha*
62. *Viburnum nersum*

Shrubs

1. *Aechmanthera gossypina*
2. *Berberis aristata*
3. *Boehmenia rugulosa*
4. *Budleja sp*
5. *Cersium verutum*
6. *Clematis roylei*
7. *Cornus oblonga*
8. *Cotoneaster bacillaris*
9. *Cyathula tomentosa*
10. *Daphne cannabina*
11. *Daphne papyracea*
12. *Desmodium gangeticum*
13. *Deutzia staminea*
14. *Euphorbia prolifera*
15. *Ficus scandens*
16. *Flemingia sambuense*
17. *Gaultheria nummularioides*
18. *Girardeia heterophylla*
19. *Hypericum oblongifolium*
20. *Indigofera heterantha*
21. *Jasminum humile*
22. *Leptodermis kumaonensis*

23. *Lespedeza sp.*
24. *Lonicera quinculocularis*
25. *Myrcine africana*
26. *Nerium sp*
27. *Osbeckia stellata*
28. *Philadelphus sp.*
29. *Pouzolzia sp.*
30. *Pyracantha crenulata*
31. *Randia tetrasperma*
32. *Rhamnus virgatus*
33. *Rubus biflorus*
34. *Rubus ellipticus*
35. *Rubus foliolosus*
36. *Rubus paniculatus*
37. *Sarcococa saligna*
38. *Trachelospermum lucidum*
39. *Urtica dioca*
40. *Urtica hyperborea*
41. *Urtica parviflora*
42. *Zanthoxylum acanthopodium*
43. *Zanthoxylum armatum*

Herbs

1. *Adiantum venustum*
2. *Ainsliaea sp.*
3. *Ajuga parviflora*
4. *Anaphalis sp.*
5. *Anemone tetrasepala*
6. *Anemone vitifolia*
7. *Arabis amplexicaulis*
8. *Arisaema flavum*
9. *Artemisia nilagarica*
10. *Artemissia nilgarica*
11. *Asparagus racemosus*
12. *Aster molliusculus*
13. *Aster sp.*
14. *Bergenia sp.*
15. *Bistorta amplexicaulis*
16. *Boeninghausienia albiflora*
17. *Calanthe sp.*
18. *Cannabis sativa*
19. *Cardamine impatiens*
20. *Cirsium wallichii*
21. *Cissampelos pariera*
22. *Condrus crispus*

23. *Conyza stricta*
24. *Crassocephalum sp.*
25. *Curculigo sp.*
26. *Cyanoglossum zeylanicum*
27. *Datura stramonium*
28. *Desmodium triquetrum*
29. *Dioscoria deltoidea*
30. *Elsholtzia eriestachya*
31. *Epilobium sp.*
32. *Erigeron himalayansis*
33. *Eulophia compestris*
34. *Eupatorium adenophorum*
35. *Eupatorium odoratum*
36. *Flemingia strobilifera*
37. *Fragaria sp.*
38. *Fragaria vesca*
39. *Geranium wallichianum*
40. *Gnaphalium sp*
41. *Goodyera biflora*
42. *Hedychium spicatum*
43. *Impatiens urticifolia*
44. *Inula cappa*
45. *Lonicera sp.*
46. *Lysimachia sp*
47. *Onychium contiguum*
48. *Origanum vulgare*
49. *Osyris quadripartila*
50. *Oxalis corniculata*
51. *Parietaria debile*
52. *Pilea sp.*
53. *Plectranthus coesta*
54. *Plectranthus striatus*
55. *Polygonum amplexicaule*
56. *Polygonum chinense*
57. *Polygonum recumbens*
58. *Potamogeton sp.*
59. *Potentilla fulgens*
60. *Potentilla sp.*
61. *Rosularia rosulata*
62. *Rubia sp.*
63. *Rubus nutans*
64. *Rumex hastatus*
65. *Satyrium nepalense*
66. *Scrophularia calycina*
67. *Seigesbeckia chinensis*

68. *Selinum sp.*
69. *Senecio rufinenervis*
70. *Senecio sp.*
71. *Solanum indicum*
72. *Solidago virgaurea*
73. *Stellaria sp.*
74. *Swertia augustifolia*
75. *Tectrastigma affine*
76. *Thymus serpyllum*
77. *Valeriana wallichii*
78. *Viola odortus*
79. *Wikstroemia canescens*

Grass

1. *Apluda mutica*
2. *Arundinella nepalensis*
3. *Arundo spp,*
4. *Bothriochloa pertusa*
5. *Carex cruciata*
6. *Chimonobambusa falcata*
7. *Crysopogon gryllus*
8. *Cymbopogon martinii*
9. *Cynodon dactylon*
10. *Eragrostis spp.*
11. *Eragrostis unioloides*
12. *Erianthus munja*
13. *Heteropogon contortus*
14. *Imperata cylindrica*
15. *Mondo intermedius*
16. *Neyraudia arundinacea*
17. *Pennisetum orientale*
18. *Poa annua*
19. *Saccharum spontaneum*
20. *Sporobolus diander*
21. *Themeda anathera*

Creeper

1. *Cissampelos sp*
2. *Clematis buchananiana*
3. *Gloriosa superba*
4. *Hedera nepalensis*
5. *Hoelbolia latifolia*
6. *Marsdenia lucida*
7. *Marsdenia roylei*
8. *Parthenocissus himalayana*

9. *Rhamnus prostratus*
10. *Smilax aspera*
11. *Smilax vaginata*

Pteridophytes

1. *Asplenium dalhousiae*
2. *Athyrium sp.*
3. *Coniograme sp.*
4. *Cyrtomium caryotedium*
5. *Dicranopteris linearis*
6. *Dryopteris juxtaposita*
7. *Dryopteris wallichii*
8. *Hypolepis punctata*
9. *Polystichum sp.*
10. *Polysticum squarossum*
11. *Pteris biaurita*
12. *Pteris cretica*
13. *Pteris sp.*
14. *Woodwardia unigemmata*